STRANGE PHENOMENA

A SOURCEBOOK OF UNUSUAL NATURAL PHENOMENA

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PREFACE TO STRANGE PHENOMENA VOL. G2

More than six months have passed since the publication of STRANGE PHENOMENA, vol. G1. During that period, the general format of the sourcebooks has been tested, found useful, and in need of no major modifications.

Volume G2 is similar to vol. Gl except in emphasis. Falling material (GFx) and solar, lunar, and planetary effects (xxS) are given more play, whereas Gl was strong on luminous phenomena (GLx) and sound phenomena (GSx). A considerable backlog of material exists, and vol. G3 will appear in due course. —-

The enterprise producing the sourcebooks has been given the nondescript name: The Sourcebook Project——any other name would be presumptious and officious. Bulletins are issued occasionally, as buyers are well aware. The Project has also published the first sourcebook in the "ancient man" series, STRANGE ARTIFACTS, vol. M1. Volumes on geology and astronomy will appear soon. To quote Tennyson, the purpose of the Sourcebook Project is:

To follow knowledge like a sinking star,
Beyond the utmost bound of human thought.

A bit melodramatic for these days, but not bad at all. Meanwhile, it seems pertinent to reproduce the Preface from vol. G1.

PREFACE TO STRANGE PHENOMENA, VOL. G1

I have always been intrigued with the tailings from the mine of science. I mean hose facts that do not fit the mold, those anomalies that should not exist, those sports, those wild points that lie far off the curve. One of my hobbies is collecting and organizing these homeless facts. These waifs are curious and most intriguing. Either they are false or science still has much fundamental work to do. But I leave such problems to the reader. All I have done is collect, categorize, and reprint this anomalous information. The result is this first volume of geophysical curiosities. Perhaps you can make something out of them. At the very least, I hope you will be excited by the unknown territory that still lies ahead of us.

I have devoted a great deal of thought to the organization of this volume. The format is flexible. More material may be added within the framework of categories from any source and any period. Seemingly disparate data are correlated through the indexes and annotations. Whole new categories can be added if it appears necessary.

The literature dealing with mysterious geophysical phenomena has been merely scratched. Volume G1, the present volume, represents only a small portion of my collection. Volume G2 is well along in preparation, as are volumes in the fields of ancient man and unresolved geological problems.

The data included have been filtered only slightly. Doubtless some hoaxes and honest misinterpretation will be found in the pages that follow. This is unavoidable in a project of this scope. Indeed, it is unavoidable in all phases of inquiry, especially those relying heavily upon observational evidence. Data were selected for inclusion according to their "strangeness" and their tendency to contradict current scientific hypotheses or stretch them beyond their present bounds. There has also been a deliberate effort to gather in observations from the 19th Century that have gathered dust too long on library shelves. Anomalous events are too rare to let them be discarded merely because they are old or money cannot be found to put them into

computerized data systems.

The collecting new I flung into the literature was a broad one. It had to be because (1) valid data and good theories are often published outside the mainstream of scientifi thought; and (2) people were just as observant a century or two ago as they are today. Quotations in this volume will demonstrate that they viewed the world with great curiosity and if they sometimes misinterpreted things perhaps they also saw the cosmos through less biased eyes.

Some of the material included here will be labelled "pseudoscience, " but some of the data so castigated will be legitimate science a decade hence. Meteorites are, of course, a classic case in point. The reader should bear in mind that many items are inserted with the express purpose of "rocking the boat. "

I should also add that I have deliberately introduced data——perhaps 25% of the whole——from outside the scientific literature. This was not done because of any lack of material but rather to insure the widest possible spectrum of observations.

Being that this is a sourcebook. I must acknowledge the many writers of papers, books, letters-to-the-editor. and sundry publications that form the foundation of the book. Where lengthy quotations are taken from publications still protected by copyright, permission has been obtained from the copyright holder.

William R. Corliss

Glen Arm, Maryland
June 16, 1974

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*A breakdown of the subsections within these categories follows. Use the headings at the tops of the pages to locate specific subsections and entries.

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		*GGT	Time anomalies
GH	Hydrospheric anomalies	*GHG	Geysers and wells
		*GHP	Unusual agitations
		*GHS	Lake oscillations
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		*GHW	Unusual waves
Gl	Incendiary phenomena	*GIC	Unexplained fires
		*GIF	Firestorms
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		GLB	Ball lightning
		GLD	Electric discharge
		GLL	Lightning
		GLM	Meteor-like phenomena
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		GSM	Music, bells, etc.
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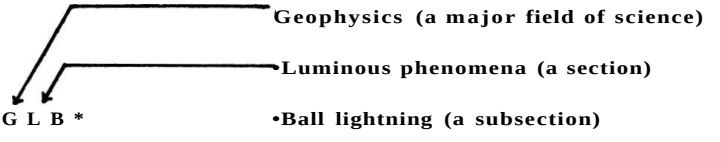
•This subsection not represented in Volume G2.

ORGANIZATION OF THE SOURCEBOOKS

All sourcebook entries are labelled with three letters and a number; viz., GLB-012. The three letters indicate a category of phenomena. GLB, for example, designates a subsection of the book containing accounts of ball lightning. The number following the letters is simply an acquisition number within that subsection. Thus, entry GLB-012 is the 12th entry in the ball lightning category. The indexes at the back of each sourcebook and all cross references are keyed to the entry number rather than page number.

There is a plan to the assignment of letter codes. The first letter indicates a broad, general field of science, such as geophysics, G. The second and third letters are assigned to sections and subsections within this general field, as illustrated below:



The sections denoted by the second letters are based upon the primary physical sensation evoked by the phenomenon at hand. Ball lightning is primarily a luminous event and thus bears the GL label. Of course, ball lightning also makes noise on
^^occasion and sometimes leaves an odor behind, but these are secondary attributes.

^^The subsections (third letters) are narrower in scope than the sections. Experience, however, has shown that subsections must be broad to encompass the great variety of phenomena in a reasonable number of categories. They cannot be too broad, though, or a structureless hodgepodge results. The subsections have been selected and named with great care to avoid suggesting explanations of the phenomena. A complete list of sections and subsections now in use precedes this page and also functions as a table of contents. Detailed descriptions of the subsections are placed at the beginnings of the sections.

When searching for a specific entry," scan the running heads at the tops of the pages; they give the entry numbers as well as the subsection titles. The person who reads for curiosity's sake will find that each subsection is much like a chapter, with many related items grouped together.

Some larger works, especially books, cover so much ground that their contents have been split up into the appropriate subsections.

The loose-leaf format of the sourcebooks makes it possible to combine material sub-section by subsection as new volumes are issued.

Each volume is indexed by subject, by time-of-event, by place-of-event, by author, and by data source. Each volume is self-contained. With the issuance of future volumes, cumulative indexes will be compiled. There will be no necessity to hunt
Bthrough several indexes to find something. Because some major fields are inter-related, it will doubtless prove useful to cumulate indexes from volumes on geo-physics, astronomy, geology, and so on.

*

ORGANIZATION OF THE SOURCEBOOKS

References, annotations, and Compiler's Summaries are printed full-width, while all direct quotes are indented.

Being a sourcebook, the core of this volume consists of the direct quotations from eye-witnesses and key investigators. The text herein faithfully retains the old spellings, punctuations, and even a few typos. After all, only the eye-witness' own words convey the facts as he perceived them. Regurgitations and surveys, so common these days, are already once or twice removed from the event. The whole object of these sourcebooks is to give the reader and researcher an organized collection of original writings on the unusual facets of nature. Much of this unique information is being lost as libraries become more highly computerized. Data selected for the data banks must have current relevance and be acceptable to the science of the day. Hopefully, these sourcebooks will preserve something of value and help focus the diverse, widely dispersed anomalies on the frontiers of science. They should also be interesting reading.

SECTION GE:
ELECTROMAGNETIC PHENOMENA

Included here are those unusual geophysical phenomena that apparently depend upon the reflection, refraction, and transmission of electromagnetic radiation. The descriptions of the subsections that follow elaborate on what is and what is not included.

GEB **Brocken Spectres, glories, and similar phenomena. The following are <u>not</u> included: haloes, sun pillars, mock suns, and mock moons. Such phenomena are considered common and fairly well understood.**

***GEG** **Radar angels. Unexplained radar echoes, including studies of insects and temperature anomalies as possible causes.**

GEM **Unusual mirages. Fata Morgana, cities in the sky, marching troops, etc., with explanations, where possible. Most mirages are easily explained and are not included.**

***GER** **Planetary resonances. Behavior of electromagnetic waves in the earth's ionospheric cavity. Whole-earth as a resonator.**

GET **Transmission phenomena. Unusual radio reception. Delayed echoes.**

•This subsection not represented in Volume G2.

ELECTROMAGNETIC PHENOMENA

GEB-005 [BROCKEN SPECTRE PHENOMENON]

Anonymous; Nature, 21:216, January 1, 1880.

Writing to the Western Daily Press under the date of December 22, 1879, Prof. Silvanus Thompson says:——1 had the opportunity about half-past ten this morning of witnessing from Clifton Down a phenomenon which enjoys the repute of being very rare. The entire gorge of the Avon was filled with mist, so that the river in the bottom and the Leigh Woods opposite were quite obscured. Standing on the western extremity of the Observatory Hill, I observed a dim gigantic figure apparently standing out through the mist upon one of the lower slopes of Clifton Down, where it runs down in undulating ridges from the promenade towards the river. A moment's glance sufficed to show me that it was my own shadow on the mist, and as I waved my arms about the gaunt spectre followed every movement. A gentleman who stood beside me likewise saw his spectre, but not mine, as we ascertained by the movements executed; nor could I see his, unless we stood so close together that the spectres seemed combined into one. The analogy presented by these spectres with the famous Spectre of the Brocken, seen by travellers in the level rays of the morning sun from the summit of that celebrated mountain, and described by Sir David Brewster in his "Letters on Natural Magic," is very striking.

GEB-006 THE CIRCLE OF ULLOA

Zurcher, Frederic; Meteors, Aerolites, Storms, and Atmospheric Phenomena, C. Scribner & Co., New York, 1876.

The following description is attributed to Ulloa.

He was on Pambamarca with six companions at daybreak. The top of the mountain was entirely covered with dense clouds. As the sun rose, it dispelled these clouds, and nothing remained in their stead but some very light mists, which it was almost impossible to distinguish. Suddenly, on the side opposite that in which the sun rose, each of the travellers saw, at a dozen fathoms from where he stood, an image of himself reflected in the air, as though upon a mirror. This image appeared in the centre of three rainbows shaded with different colors, and surrounded at a certain distance by a fourth arch of a single color. The tinting farthest on the outside of each arch was flesh-colored, or red, the next shade was orange, the third was yellow, the fourth straw-color, and the last one green. All these arcs were perpendicular to the horizon; they moved about and followed the person reflected in every direction, surrounding his image like a gloria. What was most remarkable was, that, although the seven travellers stood together in a single group, each of them saw the phenomenon only in relation to himself, and was-disposed to deny its existence in reference to the others. The extent of these arches increased progressively in proportion to the height of the sun. At the same time their colors faded away, the spectra became paler and paler and more vague, and at last the phenomenon entirely disappeared. When this display began, the shape of the arcs was oval; and, toward the last, it was perfectly circular, (pp. 178-179)

GEB-007 BROCKEN SPECTRES, GLORIES, ETC.

GEB-007 AERIAL SPECTRES

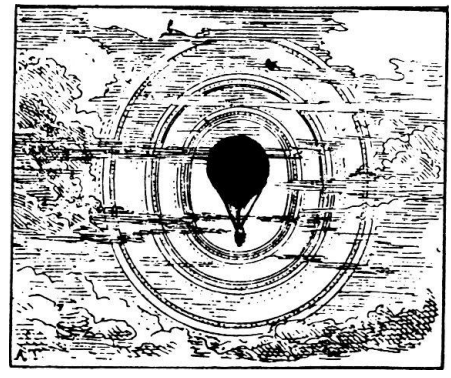
Anonymous; Nature, 8:227-228, July 17, 1873.

In an article on the above subject in La Nature, No. 4, M. G. Tissandier gives the following account of what he saw from a balloon on February 16, last.

At mid-day we quitted the earth wrapped in a thick mantle of fog; after traversing the mass of the clouds, we were suddenly dazzled by torrents of light which shot from a tropical sun, a stream of fire, in the midst of an azure sky. Neither the mer de glace nor the snowy fields of the Alps, give an idea of the plateau of mist which stretched under the car like a glassy circle, in which valleys of silver appeared in the midst of flakes of gold. Neither the sea at sunset nor the ocean waves when lighted up by the orb of day at noon, approach in splendour this array of circular cumulus, but which have, in addition, "the light that never was on sea or land. "

When our balloon had passed about 50 metres beyond the plain of clouds, its shadow was projected with remarkable precision, and a magnificent circular rainbow appeared round the shadow of the car. Fig. 2 gives a very exact idea of the phenomenon. The shadow of the car formed the centre of rainbow-coloured concentric circles, in which were distinctly seen the seven colours of the spectrum, violet, indigo, blue, green, yellow, orange, and red. The violet was inside, and the red on the outside, these two colours being at the same time those which were seen with the greatest distinctness. We were, at the time the observation was made, at a height of 1,350 metres above the level of the sea.

The balloon, the gas in which expanded under the heat of the sun, continued to rise rapidly in the air, its shadow visibly diminishing; soon, at a height of 1, 700 metres, the rainbow-circle enveloped it entirely, and disappeared from around the car. A little later, at about l*' *35"*, we approached the bed of clouds and the shadow was girt this time by three silver-coloured aurioles, elliptical and concentric, as shown in Fig. 1.



Shadow of a balloon surrounded by three aureoles from GEB-007.

Nothing can give an idea of the purity of these shadows, which are cut out in an opaline mist, or of the delicacy of tone of the rainbow which surrounds them. The complete silence which reigns in the aerial regions, where this play of light is seen, the absolute calm which exists there, above clouds transformed by the sun into flakes of light, adds to the beauty of the spectacle, and fills the soul with inexpressible admiration.

We do not yet know exactly to what cause to attribute the production of a luminous contour around the shadow projected upon vapours or mists. Some observers have thought that these phenomena are due to the diffraction of light, but it is possible that they have a common origin with the rainbow. What tends to confirm this opinion is the necessity for the presence of the vapour of water as a necessary condition of the phenomenon: if it is the result of diffraction, it ought to appear as well upon a white wall, or any kind of screen, as upon a cloud. It is possible, moreover, to study these curious phenomena by means of experiments upon the earth; by suitably arranging screens of silk or muslin saturated with water, which resemble a cloud, we may expect to be able to produce the phenomenon. M. Leterne points out another excellent method of studying it. On a spring morning, when the sun, about 15 or 20 degrees above the horizon, has warmed the atmosphere a little, and has produced a light condensation of vapour upon the grassy borders of the roads, one may see his silhouette projected upon the humid verdure, surrounded by a luminous contour, in which is seen the colours of the spectrum, the red, however, being strongest.

GEB-008 LUMINOUS HALOS SURROUNDING THE SHADOWS OF HEADS

Evershed, J., and Fermor, L. L.; "Nature, 90:592-593, January 30, 1913.

The phenomenon referred to in a note in Nature of December 12 (p. 419) [GEB-012], as observed in rice-fields of Japan, can also be seen on grass when the sun is low in the sky. The presence of dew, I believe, increases the intensity of the halo, but it is perfectly distinct also on dry grass.

If the grass surface is near to the observer, a faint halo is seen to surround the shadow of his head, and this is more easily perceived if he is moving than if standing still; my attention was indeed first attracted to the phenomenon when bicycling.

In this mountain region I have frequently seen the halo projected on a grassy slope a mile or more distant, and under these conditions it appears as a circular or elliptical patch of light without the central shadow, the diminution of intensity due to the penumbral shadow of one's head being, of course, quite inappreciable at such distances. It is difficult to determine the size or shape of this patch, owing to irregularities in the brightness of the background; but I have been able to compare it with the nearly full moon rising immediately above it, and should judge it to be at least 2 in diameter, and probably elliptical in shape with the long axis vertical. The light appears to emanate from the grass itself, which apparently reflects more light in the direction of incidence than in other directions; it is certainly not due to dust or haze in the intermediate column of air. I am unable to say whether a smooth rock surface would give the same appearance, but a dense white cloud certainly does so, with the addition of a faintly coloured ring surrounding the white patch. This I presume is allied to the "Brocken spectre," seen when the illuminated cloud or fog is near to the observer.

GEB-008 BROCKEN SPECTRES, GLORIES, ETC.

The analogy of this elliptical bright patch opposite the sun with the Gegenschein is so striking that one cannot help believing both to be due to the same cause, and that matter outside the earth's orbit and beyond the limits of the earth's shadow reflects more sunlight in the direction of incidence than in other directions. That the Gegenschein usually covers a much larger angular area than the 2° patch seen on these hills may be accounted for by the much more favourable conditions in which it is seen, with a dark and uniform sky-background. (J. Evershed.)

Exactly a month ago to-day, in the Betul district, Central Provinces, I had set out on field work at dawn, with my cotteague, Mr. H. Walker, and two chaprasis (Indian servants). I happened to be watching our shadows as we passed along the edge of a field of young green wheat, when, to my surprise, I noticed a halo of light round the shadow of my own head and neck. Looking at the other shadows, I was still more surprised to see that only my shadow was invested with this halo. I directed the attention of Mr. Walker and the chaprasis to the phenomenon, and found that each could see a halo round his own head only. Whilst we were investigating the matter our camp passed on the march, and inquiries made both from our servants and from local people showed that none of them had previously noticed the phenomenon.

The conditions were obviously special, although frequently obtainable to one who deliberately set out with the purpose of finding them. The sun was at a low altitude on our left, and the wheat was soaking wet with dew on our right. The dew speedily dries up in the morning sun, and although I have kept on the look-out for this phenomenon during the past month I have never happened to pass a wheat-field again with the conditions of time, situation, and wetness repeated.

I had, therefore, intended writing to Nature to inquire whether the occurrence of these halos had been previously recorded, and consequently was greatly interested to read the note on p. 419 of your journal (December 12, 1912) concerning Inada no goko, or halo in the ricefield. I have not seen the Japanese journal referred to, and consequently am not aware if Profs. Fuchino and Izu direct attention to the fact noted above, that each observer sees the halo round his own head only. This fact indicates that the observer perceives those elements of a narrow cylinder of the sun's rays enclosing his head that happen to be reflected back to his eyes by the dewdrops and wheat blades; the major portion of the cylinder of light is reflected back along the cylinder, and consequently a given observer is not in the line of vision for the halo round another observer's head. The explanation advanced by the Japanese observers that the halo "is caused by the reflected light from the sun-images formed on the green blades by the passage of the sun's rays obliquely through the dewdrops" is doubtless correct. I presume that their investigations show that the farther a drop is from the edge of the shadow of the head the smaller is the proportion of the light reflected from the sun-images that can reach the observer's eye; for the boundary of the halo is not sharp, the brightness diminishing somewhat gradually with distance from the shadow. Assigning to the head in the shadow the actual diameter of the head, I estimated the noticeably bright part of the halo as roughly 10 in. wide all round the head, dying out on the shoulders.

A close inspection of the green blades showed that at or near the tip of each blade was one pearl of dew, whilst the whole of the remainder of the blade was coated with a film of minute dewdrops. It is the minute drops that give rise to the major portion of the effect.

The fact that each observer sees only his own halo obviously precludes this phenomenon from having been the origin of the halos recorded in sacred writings round the head of Christ and others. (L. L. Fermor.)

GEB-009 LUMINOUS HALOS SURROUNDING THE SHADOWS OF HEADS

Fisher, O., et al; Nature, 90:621-622, February 6, 1913.

I remember when I was a boy, more than eighty years ago, that I used to notice this luminous halo surrounding the shadow of my head on the water when I was fishing from a bridge in the meadows below Salisbury. I think it was in some way connected with the ripple on the water, which was so clear that I could see the fish. I mention this because similar conditions could be easily met with. (O. Fisher.)

This phenomenon may sometimes be seen in this country when one's shadow falls on grass. It is not necessary that the grass should be wet, if the leaves have a shining cuticle; but the general direction of the blades (which grow usually more or less parallel to one another) in relation to the position of the sun at the time must be such that its rays strike their surface at an angle approaching a right angle. Under these conditions the blades of grass from which most light reaches the observer's eye are those upon which the sun's rays fall, and are reflected to him, most nearly perpendicularly, and the rays which do so are those which pass closest to his head without being intercepted by it. Hence there appears to him a ring of brighter illumination immediately surrounding the shadow of his head, the effect being heightened by contrast. Farther from the shadow, as the angle of incidence becomes more oblique, the luminous ring becomes gradually merged into the general illumination. The reason why the bright ring is not seen round the lower parts of the body or around the heads of other persons is that these are not so nearly in the direct line of incidence.

The phenomenon "A Shadow and Halo" is described in Nature in 1888 by several correspondents (vol. xxxviii., pp. 540, 589, 619), and its production by reflection from dewy grass is explained on the lines I have mentioned.

An analogous phenomenon is the striped appearance of a lawn or grass field which has been rolled by a roller passing alternately in contrary directions. Where the roller has travelled in a direction from the position of the observer the blades of grass are bent away from him, and he sees light from the sky reflected from the smooth cuticle on their upper surface. Where the roller has travelled in a direction towards the observer the blades of grass are bent over towards him, so that he sees more of their under surface, which, besides being partially shaded, has not so highly reflecting a cuticle as the upper surface, hence these strips appear, in comparison with the first, darker and of a deeper green. (H. Franklin Parsons.)

With reference to the letters by Messrs. Evershed and Fermor in Nature of January 30 [GEB-008], it may be of interest that an amusing description of the appearance of halos around shadows is given by Benvenuto Cellini in his autobiography (book i., chap, cxxviii.). After being released from a well-deserved term of imprisonment, he noticed a halo round the shadow of his head, and interpreted it as a mark of the especial favour of heaven. A rough translation of the passage is as follows:——"Also I must not leave unmentioned a thing, the greatest that has happened to any man, which I tell to the glory of God and of His mysteries, who condescended to make me worthy of it. From that time. . . there remained a splendour (wondrous thing!) on my head, which is evident to all sorts of men to whom I have shown it (who have been very few). This is seen over my shadow in the morning from sunrise until two hours later, and is seen much better when the grass has dew upon it; it is visible again at sunset. I became aware of it in France at Paris, because the air there is so much more free from mist that one sees it more markedly than in Italy, where mists are more frequent."

Doubtless the "pochissimi" to whom he showed it knew him too well to confess that they saw the halo around the shadows of their own heads, not his.

I have often noticed the appearance, especially on short turf, such as that of golf links, when the grass is wet with dew, but it may sometimes be seen on dry grass. (L. Doncaster.)

GEB-010 [BROCKEN SPECTRE PHOTOGRAPHED]

Anonymous; Nature, 85:417, January 26, 1911.

La Nature for December 17, 1910, contains a photograph of the "Spectre of the Brocken," taken some time ago by M. Th. Moureaux on the terrace of the observatory of the Pic du Midi. It shows in the centre of the corona the shadow of the operator holding up the photographic apparatus. On the summit of the peak and to the westward patches of cumulus cloud were scattered over the sky, and at times the sun shone out brightly on the rising mists. The author of the note (M. J. Loisel) states that, so far as he knows, this is the first time that the spectre has been photographed. He refers to M. Lancaster's experience at Uccle at the time of a thick fog in July, 1892, during which he saw his shadow projected by a lamp burning in a room on the second floor, and all his movements reproduced. M. Loisel remarks that it would be interesting to observe whether the phenomenon would be repeated in any thick fog, or only under special conditions.

GEB-011 [HALO IN THE RICEFIELD]

Anonymous; Nature, 90:419, December 12, 1912.

The curious phenomenon known in Japan as Inada no goko, or halo in the ricefield, forms the subject of a discussion by Profs. Fuchino and Izu, of the College of Agriculture and Forestry, Kogoshima, in the Journal of the Meteorological Society of Japan (October, 1912). In the early morning, when the dew is on the plants, and the sun is shining, the shadow of the head of a person standing in the fields is surrounded by a luminous halo, elliptic in form, its long axis corresponding with that of the body-shadow. As the sun rises higher in the sky and the dew evaporates the halo vanishes, but reappears on sprinkling the ground with water. The authors describe some experiments which they carried out with blankets, isolated drops of water, and bottles. They conclude from their experiments that the phenomenon of the halo is caused by the reflected light from the sun-images formed on the green blades by the passage of the sun's rays obliquely through the dewdrops.

GEB-012 DISAPPEARANCE OF BISHOP'S RING IN COLORADO

Stone, G. H.; Nature, 35:581, April 21, 1887.

The reddish ring about the sun first distinctly appeared here (at the base of Pike's Peak) on November 22, 1883. For several days before that date, a faint discoloration of the region about the sun had attracted my attention. This gradually grew more intense, and, on the day mentioned, became unmistakable. The subsequent history of Bishop's ring as seen at this place is, in brief, as follows:-

The colour was most intense during the winter of 1883-84, and diminished in brightness from that time until its disappearance. At first it was visible almost all the time. Later, it appeared only at the time of cold storms, which were accompanied by great vertical movement of the air, or when, for any reason, the clouds reached to a great height. It was, on the average, brighter during the winters than in the summers; also, it was brighter when the sun was near the horizon. Many times in cold weather there has been not a trace of the ring, although the air was so clear that peaks a hundred miles distant were distinctly visible from the heights behind this city. At other times the ring has been very bright when the air was so hazy that the mountains only ten miles away were hardly visible. During the later months of 1885 it was invisible most of the time, but suddenly flamed out in wonderful intensity at the time of the great norther of January 9-11, 1886. Then for about two months it frequently appeared in the morning, or towards evening. During the warm months of 1886 it was not seen. On October 15 it appeared distinctly. About a week later it appeared very faintly a few times, and since then I have not been able to see a trace of it. My observations have been made at elevations of from 6000 to about 13,000 feet, and there was but little apparent difference in intensity at the different elevations. It is well known that the atmosphere here is, in general, very dry and transparent.

The diffraction-ring was often more coppery, almost rosy, in tint at the time of the northers, and in the thickening haze in the upper air preparatory to hailstorms. The great intensity of the colour at such times, and its peculiar tint, and that, too, irrespective of the amount of haze in the lower atmosphere, makes it probable that the ring was in part due to diffraction on ice-particles. If so, the ice-particles may themselves have been due to precipitation on dust-particles. The fact that no diffraction-ring has been seen around the sun during the past winter is not conclusive, for we have had no great northers, the season being unusually mild. But the disappearance of Bishop's ring for so long a time makes it certain that, even if there can be a circumsolar glow due to diffraction on ice-particles, yet the proper conditions for such a ring are realised only rarely, except when there is a great amount of volcanic dust in the air.

The Bishop's Ring phenomenon, seen elsewhere in the world, was generally attributed to the debris injected into the atmosphere during the eruption of Krakatoa.

GEB-013 VOLCANIC DUST PHENOMENA

Backhouse, T. W.; Nature, 67:174, December 25, 1902.

The phenomena connected with the volcanic dust are undergoing distinct

changes. In common with observers in the south of England, I noted the fresh appearance of the dust phenomena in the end of June, especially on June 26, but they were not very striking until August 1. At first the most decidedly volcanic feature was the great corona round the sun, known in the case of the Krakatoa effects as "Bishop's Ring." Whether this name should be applied to the corona this year is doubtful, as its radius has been fully double that of the Krakatoa corona, having until recently averaged about 70°, measured from the sun to the middle of the reddest part. Yesterday and this morning, however, it averaged only about 40 , and its reddest part was a yellowish-brown rather than a red. The colour of the corona this year has always been much less decidedly pink than was the case with Bishop's ring; indeed, it has sometimes been an absence of blueness in that part of the sky rather than any positive redness.

The pink glows after sunset were very strong in the end of June, but stronger still in November, and on November 1, 17 and 18 there was also a faint second glow, a phenomenon I had not previously seen since the Krakatoa sunsets.. . . . . .

GEB-014 THE GREEN TINTS OF SUNSET

Offord, Joseph; Nature, 75:342, February 7, 1907.

The first portion of Offord's letter contains some interesting Egyptian history relative to the "green flash. "

The appearance of a green light at sunset, like many other phenomena supposed to have only recently attracted attention, was noticed and commented upon by the ancient Egyptians, and more particularly so because in the clear air of Egypt the tints of sunset are peculiarly distinct.

As the sun there descends nearer and nearer to the horizon, apparently hastening to disappear behind one of the Libyan hills, as if burying itself in the sand at their base, the immensely enlarged flaming disc suddenly becomes, for an instant, of a brilliant green colour, and immediately a series of green rays suffuses the sky in many directions, well-nigh to the zenith.

The same phenomenon appears sometimes at sunrise, but to a smaller extent.

According to ancient Egyptian notions of cosmogony, the sun, after passing through the western gate into the world of night, travelled northward parallel to the Nile until the sixth hour, when it commenced to journey southward, having passed to the eastern side of Egypt, and, finally, at sunrise came forth by the "Gate of the East. "

Now, during the nocturnal voyage, the solar orb was said to be a disc of Mafkait, which was the title of a green-coloured mineral, and so the sun was considered from sunset to sunrise to be coloured green. Sometimes, just as the last part of the sun's disc vanishes, its colour changes from green to blue, and so also after it has disappeared the sky near the horizon is often green, whilst toward the zenith it is blue. This was alluded to in ancient Egyptian writings, where sometimes it is said that at sunrise or sunset the sun's rays were of Tahen, a blue metal, the title of which is often used in reference to the blue of the sky.

GEM-001 THE FATA MORGANA OF THE STRAITS OF MESSINA

B., G. H.; Nature 67:393-394, February 26, 1903.

Here is a nice little review of Fata Morgana observations. The standard "mirage explanation" probably suffices here, but the white mist is perplexing.

Just as the Brocken is noted for its "spectre," so the Straits of Messina have long been known as presenting, under certain exceptional atmospheric conditions, a fine display of the appearances known as Fata Morgana. On his appointment in 1899 to the chair of physics at the Technical College of Reggio, Dr. Vittorio E. Boccara undertook a historical and critical study of the phenomena, and the results of his investigation are published in the Memorie of the Italian Spectroscopists' Society, xxxi., 10.

Among the ancients, the name of Aristotle is mentioned, but his references to the Fata Morgana are doubtful. Cornelius Agrippa spoke of reflections in the air of mountains, animals and other objects; Homer, Apollonius Polycletus, Damascius, and Pliny also alluded to apparitions in the air, but their descriptions are not precise. Allusions to the Fata Morgana are also contained in the historical writings of Tommaso Fazzello (1550), Giuseppe Carnevale (1591) and Marc' Antonio Politi (1617), but the first attempt at a description of the phenomena was given by Father Angelucci in a letter published in 1671 by Athanas Kircher, in which he described the appearances seen on the morning of Assumption Day (August 15), 1634. These effects Kircher attributed to reflection by crystals in the air, and stated that he had been able to reproduce them artificially before a large audience.

In 1773, Father Antonio Minasi published a "dissertation on the phenomenon commonly called Fata Morgana," in which he distinguished three different forms, namely, marine morgana, aerial morgana and iridescent morgana. Minasi illustrated his descriptions by a remarkably good drawing showing the three phases.

In a treatise published at Naples in 1824, Captain Pietro Ribaud described the marine morgana of July, 1809, and gave a detailed account of the meteorological conditions necessary for its formation. In addition to calm, hot weather, we notice that Ribaud considered it necessary that the vapours exhaled under the heat of the sun from the heterogeneous substances, antimonious, vitreous, oleaginous, saline and other, contained in quantity in the shores and earths of Calabria and Sicily should not be carried away by the wind. Also the most favourable time for the morgana is about the turn of the tide.

The first to explain the morgana by refraction, was Prof. Salvatore Arcovito (1838), who, however, considered the phenomenon similar to parhelia. Cacopardi never saw the morgana himself, but followed the views of Minasi and Kircher. Regaldi saw the phenomenon on July 20, 1848, and describes how parts of the coast suddenly appeared, standing, so to speak, in the middle of the channel.

Coming to recent times, we have a description in the Zagara for 1871 by an anonymous writer. A white streak of mist passing across the Sicilian coast melted like a transparent veil, revealing arches, towers and colonnades floating on the sea, houses, and woods of many colours.

Not less explicit is Prof. Filippo Capri, who described in the Zagara the Fata Morgana of June 20, 1874, which occurred between 8 and 9 a.m. The weather was so hot as to ruin the crop of bergamot fruit, and the phenomenon, as on other occasions, was preceded by a white mist. Buildings were seen to become elongated, while the shores, with their villas and trees, became de-

tached like islands and then disappeared. In answer to the invitation for an explanation. Dr. Diego Corsa repeated Minasi's erroneous opinions, but this point of view was attacked by Prof. Canale, who, however, did not venture to formulate a theory of his own, having only seen the phenomenon once.

Prof. Boccara speaks from personal knowledge of three displays of the Fata Morgana under its three different forms——namely, an aerial morgana on June 27, 1900, witnessed by himself, Captain Vincenzo Ponzi, of Chiaggia, and Prof. Enrico Puccini; a marine morgana on July 2, 1901, also seen by Prof. Puccini; and a multiple morgana on March 26, 1902. The first is well shown by the author's sketch in Fig. 1, Fig. 2 giving an idea of the white mist seen just before the occurrence of the phenomenon, and which disappeared when the occurrence took place. In it, the houses on the Italian coast at Gallico and the point of Catona are seen to be considerably elongated in a vertical direction, and, so to speak, projected on the Sicilian coast beyond, the straits appearing to be converted into a gulf. In the marine morgana of 1901, a cloud again formed just previously, and the appearance was presented of arches standing below the sea line in an upright position, their bases having no visible foundation. These arches corresponded to some railway arches above the cemetery of Messina, but were more brilliant and larger than the real arches. Of the third, or multiple morgana, Prof. Boccara has given an illustration in Fig. 3, which, however, represents simultaneously various phases of the phenomena which were in reality seen in succession. Thus the three houses at the left were not all visible at the same instant; when one appeared, the other disappeared. The white band with vertical dark stripes was attributed to the wall of the citadel at Messina, and it appeared to blot out the houses of the town.

Prof. Boccara attributes all these phenomena to variations in atmospheric density, which produce refraction effects. It may be suggested to the mathematician that consideration of the principle of least time for the path of a light ray affords an easier way of thinking of the conditions necessary for the phenomenon than is given by the sine law of refraction. The term Fata Morgana is used by the author exclusively in connection with apparitions in which the images are erect. When inversion takes place, so that the phenomena are due to reflection, the effect is a mirage, a phenomenon also seen not unfrequently on the Sicilian coast.

The neighbourhood of Reggio is peculiarly adapted to the display of the Fata Morgana both by its topographical peculiarities and by the meteorological conditions not unfrequently existing there. These conditions are, a morning hour, hot weather, extreme clearness of the air, combined, however, with a thin veil of mist over the Sicilian coast, arid a calm air or slight wind from the north, as conditions for the marine morgana. For the aerial morgana, the best time of day is from 10 a. m. to 1 p. m., with a stratum of light cloud on the coast of Sicily, sea calm or nearly so, a high temperature and wind as before. A multiple morgana is, of course, of much rarer occurrence than the simple form, and the one seen in March, 1902, was less marked than one observed about twenty years previously by Prof. Scerbo and Signor Aloi, of which a sketch is reproduced in Dr. Boccara's paper.

GEM-002 UPS AND DOWNS OF THE HORIZON

Frazer, Calvin; Popular Mechanics, 52:242-246, August 1929. (Reprinted by permission of Popular Mechanics; copyright, the Hearst Corp.)

The magnification of objects in a mirage is rather common. Apparently the atmosphere can act as a lens. Nevertheless, the effects, like those of the Brocken Spectre, are very peculiar. Frazer gives some instances.

Many interesting and remarkable cases of looming have been reported from other parts of the world. In some of these, objects not only seemed to be lifted above their normal positions but also to be drawn out vertically on account of unequal refraction at different heights (a phenomenon sometimes called "towering") or to be otherwise distorted. People who have seen St. Joe from Chicago all remark that the buildings in the distant city appear too large. Thomas Jefferson, in his "Notes on the State of Virginia." tells of an instance in which a canoe containing three men, seen at a great distance from Yorktown, was mistaken for a ship with its three masts.

He was much interested in the effects of atmospheric refraction on distant mountains as seen from Monticello. Of this, he says:

"There is a solitary mountain about forty miles off in the south, whose natural shape is a regular cone, but. . . . it sometimes subsides almost totally in the horizon; sometimes it rises more acute and more elevated; sometimes it is hemispherical; and sometimes its sides are perpendicular, its top flat and as broad as its base. In short, it assumes at times the most whimsical shapes, and all these perhaps successively in the same morning. "

During the French military expedition to Algeria, in May, 1837, M. Bonnefont, a scientific member of the expedition, observed a flock of flamingos about three and a half miles away. As they started to fly, they assumed such enormous dimensions as to give the idea of Arab horsemen defiling one after the other. So complete was the illusion that a spahi was sent to reconnoiter.

When he reached the point where the birds had been observed, his horse's legs were seen to become so elongated that the animal appeared to tower many yards above the desert.

The sun, when close to the horizon, normally assumes an oval form, much flattened below, because refraction is greater on the lower side of the disk than on the upper. At times, however, on account of marked inequalities in air density, it is seen to be distorted into a great variety of queer shapes. It may take the form of a boy's top, a soldier's trench helmet, a mushroom, etc. or even divide into two separate and much flattened suns. The disk of the moon undergoes similar distortions. Many descriptions and pictures of these curious appearances have been published, including a large collection of photographs taken at Lick Observatory, on the summit of Mount Hamilton, California. The examples shown in the accompanying illustration were drawn in the Antarctic by Doctor Arctowski, of the "Belgica" expedition.

Some kinds of atmospheric refraction are especially common in the polar regions, and in two cases this phenomenon appears to have been responsible for celebrated geographical errors. In the first case, Lieutenant Wilkes, of the United States exploring expedition, charted the coast of the Antarctic continent at several places where subsequent explorers found only water, and a controversy has raged for generations over the merits of his discoveries. Probably Wilkes was misled by the looming of the land and greatly misjudged its distance. The second case was that of the mythical Crocker Land, which Peary thought he discovered in 1906. After it had figured on the maps for years, it was proved to be non-existent, but the Crocker Land expedition, which went north to explore it, saw from the mountains of Grant Land the same great loom of the arctic ice that Peary had mistaken for land.

On the other hand, Captain Scott, Borchgrevink, and other polar explorers, have at times found looming a useful means of locating both land and ice fields

lying beyond the normal range of visibility. Toward the close of the eighteenth century, while Napoleonic wars were in progress, an English philosopher, Doctor Vince, suggested posting lookouts to watch for the loom of approaching French warships. About the same period, popular interest was aroused in the claims of a Frenchman named Bottineau, a resident of Mauritius, who was said to be able to detect vessels at a distance of hundreds of miles by means of peculiar appearances in the sky. It is probable, however, that Bottineau's so-called art of "nauscopy" was either humbug or based on self-delusion, and had nothing to do with atmospheric refraction.

The matter of Bottineau will be taken up in another sourcebook series, because his capabilities seem to have more closely allied to dowsing and other presumably psychic phenomena.

GEM-003 FATA MORGANA

Macray, J.; Notes and Queries, 1:9:267, March 25, 1854.

Not having met with the following account in any English newspaper, of a phenomenon said to have been witnessed quite recently in Germany, I beg to send you a translation from the Allgemeine Zeitung (generally quoted in England by the name of the Augsburgh Gazette) of February 13, detailing, in a communication from Westphalia, the particulars of a phenomenon, new, perhaps to your pages, but by no means new to the world.

"Westphalia.——If the east has its Fata Morgana, we, in Westphalia, have also quite peculiar natural phenomena, which, hitherto, it has been as impossible to explain satisfactorily, as to deny. A rare and striking appearance of this description forms now the subject of universal talk and comment in our province. On the 22nd of last month a surprising prodigy of nature was seen by many persons at Buderich, a village between Unna and Werl. Shortly before sunset, an army, of boundless extent, and consisting of infantry, cavalry, and an enormous number of waggons, was observed to proceed across the country in marching order. So dintinctly seen were all these appearances, that even the flashing of the firelocks, and the colour of the cavalry uniform, which was white, could be distinguished. This whole array advanced in the direction of the wood of Schafhauser, and as the infantry entered the thicket, and the cavalry drew near, they were hid all at once, with the trees, in a thick smoke. Two houses, also, in flames, were seen with the same distinctness. At sunset the whole phenomenon vanished. As respects the fact, government has taken the evidence of fifty eye-witnesses, who have deposed to a universal agreement respecting this most remarkable appearance. Individuals are not wanting who affirm that similar phenomena were observed in former times in this region. As the fact is so well attested as to place the phenomenon beyond the possibility of successful disproof, people have not been slow in giving a meaning to it, and in referring it to the great battle of the nations at Birkenbaum, to which the old legend, particularly since 1848, again points. "

Numerous tales exist of armies seen in the sky. While there is doubtless some exaggeration by witnesses, these visions, like those at Fatima and the sightings of UFOs by many observers, may have psychic causes as well as atmospheric.

GEM-004 ATMOSPHERIC REFRACTIONS AT THE SURFACE OF WATER

Anonymous; Monthly Weather Review. 24:371-373, October 1896.

A further contribution to this subject will be found in a note by M. Andre Delebecque (Paris Comptes Rendus, August, 1896, CXXIII, p. 387) "On the extraordinary refractions observed on the borders of lakes and known by the name of fata morgana." He says:

In general this phenomenon is characterized by the fact that objects situated on the opposite shore of the lake seem to be distorted in an extraordinary way in a vertical direction; the rocks, the walls, and the houses appear to be transformed into immense constructions, out of which the imagination of the Italians has evolved the palaces of the Fairy Morgana. The fata morgana are extremely fleeting phenomena and do not generally last more than a few minutes. When they disappear the object whose vertical dimensions had been so magnified often assumes extraordinarily small proportions. As both Mr. Ford and myself have observed, the fata morgana occupies only a very limited and perpetually changing segment of the horizon, and quite near to it entirely different refractions frequently take place. On Lake Leman I have only observed them in calm weather and when the temperature of the air is notably warmer than that of the lake. They are most beautiful in the months of March, April, and May.

Many scientists, among whom I may cite Humboldt, Woltmann and Charles Dufour, have spoken of the fata morgana, but up to the present time, as far as I know, no one has given a satisfactory explanation of it, for when the air is warmer than the water of the lake, we sometimes observe the fata morgana, but more often the mirage known under the name of "mirage over cold water" and which has been so well studied by Bravais (see Bravais, Notice sur le Mirage, Ann. Met, de France, p. 256, 1852). In this latter mirage distant objects have their vertical dimensions much reduced. It seems singular that the same thermal conditions should produce two mirages so diametrically opposite to each other. The following is, I believe, the correct explanation of this apparent anomaly:

Many times when viewing the fata morgana through a powerful glass I have observed that the objects are not really increased in size, but that the impression is produced by the superposition of several images of the same object, sometimes upright, sometimes upside down. I have counted as many as five of these images. As they are generally very close together and sometime encroach one upon the other, it is very difficult to separate them by the naked eye, and therefore the illusion of an enlarged object is produced. Sometimes one portion alone produces many images. Thus, I have sometimes seen boats with two hulls, while the sails looked perfectly natural; a few minutes later only one hull remained, but the sails appeared gigantic.

It seems to result from these observations that the fata morgana is nothing more than a mirage of multiple images.

Mathematical analysis can, however, explain the facts observed.

In his memoir on the mirage, Bravais (see Bravais, Notice sur le Mirage, Ann. Met, de France, p. 264,) proves the possibility of three images being produced in the case where a layer of warm air flows more or less suddenly over a layer of cold air and when the subsequent calmness of the atmosphere allows these two layers to remain for some time in that position. But these are precisely the conditions existing during the apparition of the fata morgana, since it is necessary, as I said above, in order to produce this phenomenon that the air be very calm and perceptibly warmer than the water. The existence of three images is a particularly simple occurrence in the fata morgana. I have tried to

explain, by analysis, the production of the five images observed by me, but was obliged to give it up on account of the complexity of the calculations. In the case of three images, Bravais also shows how only certain parts of an object can produce multiple images; this phenomenon actually occurs as we have seen above.

Finally, if we reflect that two layers of air of very different densities cannot remain for a long time superposed one upon the other without becoming mixed, we shall understand the instability of the phenomenon and why the fata morgana and the mirage on cold water can succeed each other so rapidly in the same part of the lake.

The existence of multiple images infers several focussing layers in the atmosphere—— a rather complex meteorological arrangement.

GEM-005 MIRAGES, HOT AND COLD

Angell, Roger; Holiday, 8:10+, August 1950.

Some interesting excerpts from this popular article are quoted below.

* Mountain climbers have been so terrified by a form of mirage known as the "Brocken Specter" that they have lost their hold and been dashed to death. The Specter is named for Brocken Mountain in Germany, where the frightening monster was first observed. Hapless Alpinists who fall victim to this type of "looming" will suddenly have the chilly feeling that they are being watched. Looking up from the steep rock face they are ascending they will see, against a banked cloud, the huge, shadowy figures of some giant climbers, identically ascending an identical mountain. Every motion the mountaineers make is imitated by their ghostly counterparts. The "Specter, " of course, is nothing but the shadow of the climber himself, reflected against clouds and enormously enlarged by atmospheric magnification. Diffraction will often surround the image with misty, colored halos of light.

The great metropolis of mirageland is the Fata Morgana, which lies in the Strait of Messina, between Sicily and the tip of Italy. English Crusaders named the city for Morgan Le Fay, the wicked fairy sister of King Arthur. The Fata Morgana sometimes appears as an ornate and lovely suboceanic city, complete with avenues, palaces, walls and towers. Some people have even sworn to seeing inhabitants moving on its streets. When the air is warmer, the Fata Morgana appears on the surface of the water——a phenomenon which ancient mariners interpreted as a trap of the evil fairy, to lure ships into her false harbors where they would be wrecked and their crews drowned to add to the population of the underwater city.

The Fata Morgana is still visible today, on hot, windless days in the Straits. Although it is perhaps the best-known mirage in the world, its air of mystery remains, since there is not complete agreement as to just what it really is. Most experts believe that it is simply a mirage of the nearby and very real city of Messina, but there are others who have claimed that the mirage is accompanied by an extraordinary atmospheric magnification. This would mean that the Fata Morgana might well be nothing more than a tiny stretch of shore, whose pebbles, weeds and boulders were blown-up and projected seaward to become the magical city of the villainous Le Fay.

GEM-006 ON THE FATA MORGANA OF IRELAND

M'Farland, Mr.; Report of the British Association, part 2, 29-30, 1852.

The following curious quotations evoke thoughts of the legendary sunken cities off the British Isles and France, such as Lyonesse.

These singular illusions are termed in the Irish language Puna Feadhreagh, or Fairy Castles. As proof that the Morgana had appeared as an island, either resting or floating on the sea prior to 1185, Mr. M'Farland read a passage from the topographical history of that country, by Giraldus Cambrensis (lib. ii. c. 12). He then referred to the "Miranda loca, quae vidit St. Brandanus in Oceano," to which Usher alludes in his 'De Hibernia' (p. 813), and quoted an unpublished History of Ireland, composed about 1636 (and now remaining in MS. in the Library of the Royal Irish Academy at Dublin), that speaks of an "Hand which lyeth far att sea, on the west of Connaught, and sometimes is perceived by the inhabitants of the Owles and Iris; also from St. Helen Head, beyond the haven of Calbeggs (Killibegs, Donegal). Likewise, severall seamen have discovered it att sea as they have sailed on the western coasts of Ireland." Mr. M'Farland also read from the Chronographical Description of Connaught, written in 1684, by Roderick O'Flagherty, and published by the Irish Archaeological Society, in which it is recorded (p. 68), that, "From the Isles of Arran and the West continent, often appears visible that enchanted island, called O'Branil, and in Irish Beg-ara, or the Sessen Arran, set down in cards of navigation. * * There is, westward of Arran, in sight of the next continent, Skerde, a wild island of huge rocks; these sometimes appear to be a great city far off, full of houses, castles, towers, and chimneys; sometimes full of blazing flames, smoke, and people running to and fro. Another day you would see nothing but a number of ships, with their sailes and riggings; then so many great stakes or reekes of corn and turf." Mr. M'Farland next cited the 'History of the Parish of Ramoan (Ballycastle,' by the Rev. Wm. Conolly (1812), in which it is stated, that the author had received a minute description of the Fata Morgana from several persons who saw it, on different summer evenings, along the shore of the Giant's Causeway; shadows resembling castles, ruins and tall spires darted rapidly across the surface of the sea, which were instantly lengthened into considerable height; they moved to the eastern part of the horizon, and at sunset totally disappeared. This work makes mention of an earlier one (of 1748), by a gentleman who resided near the Causeway, and which presented a long account of an enchanted island, annually seen floating along the coast of Antrim. Reference was afterwards made to 'Plumptree's

Narrative' (of 1817), as showing that, at Rathlin——a considerable island opposite to Ballycastle——a belief then prevailed, that a green island rose every seventh year, out of the sea, between it and the promontory of Bengore; the inhabitants asserting that many of them had distinctly seen it, crowded with people selling yarn, and engaged in various other occupations common to a fair. The notes to the second book of Dr. Drummond's poem on the 'Causeway' were also glanced at, as containing an account of other cases of the Fata Morgana, by the Bushfoot Strand and Tor-point. So, a person still living (and whose name, &c. were given) conceived that he had a sight of the floating isle off Fair-Head; that it seemed to be well-wooded; and that he could distinguish upon it the forms of buildings, and a woman laying out clothes. Mr. M'Farland then mentioned that, in June 1833, he himself and a party of friends, when standing on a rock at Portbalintrea, perceived a small roundish island as if in the act of emerging from the deep, at a distance of a mile from the shore; at

first it appeared but as a green field, afterwards it became fringed with red, yellow and blue; whilst the forms of trees, men and cattle rose upon it slowly and successively; and these continued for about a quarter of an hour, distinct in their outlines, shape and colour; the figures, too, seemed to walk across it, or wandered among the trees, the ocean bathed it around, the sun shone upon it from above; and all was fresh, fair, and beautiful, till the sward assumed a shadowy form, and its various objects, mingling into one confused whole, passed away as strangely as they came. Further, Morgana had occasionally assumed the semblance of a beautiful bridge that spanned the Sound between the Skerry rocks and the strand at Portrush, and having people passing and repassing over it. A particular instance of this was stated, as well as of the appearance of the sea, at Ballintoy, of what resembled a city with its streets, houses, spires, &c. Two occasions were then specified, in which the Fata had been seen in the sky—the one in the summer of 1847, over the Ferry at Lough Foyle, and the other on the 14th of December 1850, near to the Bannmouth; and in the course of which the images of troops, ships, &c. were reflected on the clouds. Four other cases of the Aerial Morgana were adduced, as witnessed about the town and coast of Waterford in 1644, and at the close of the last and commencement of the present centuries, and taken from the 'Voyages and Observations' of M. le Gown, Brewer's "Beauties of Ireland" (vol. ii. p. 307, n.), and the 13th volume of the Phil. Mag., Old Series. Mr. M'Farland considered that these various exhibitions of the Fata Morgana might all be accounted for by applying to these parts of the coast on which they had been displayed, the theories of Minasi and M. Honel, as advanced by them in explanation of similar phaenomena seen on and about the Strait of Messina. The Northern Channel of Ireland presents, to a very great degree, the same data as regards shape, indentations, currents, and bitumen, as that strait does, and on which their theories rest; and he believed that, to some extent at least, so did the sea in the neighbourhood of the isles of Arran and town of Waterford. Where the Marine Morgana was found, the Aerial might be expected, and the Prismatic was a mere corollary to the first.

GEM-007 ON AN EXTRAORDINARY MIRAGE WITNESSED AT BIRKENHEAD IN CHESHIRE

Thomson, D. P. ; Report of the British Association, part 2, 39, 1847.

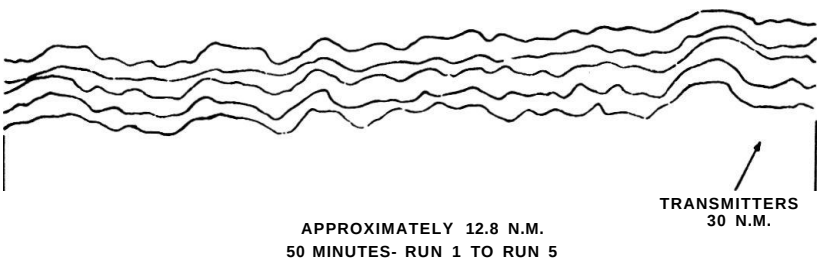
The author states that, during the exhibition of a panoramic model of Edinburgh, in the Zoological Gardens at Liverpool, on Sept. 27, 1846, about 3 p. m., an erect image of Edinburgh, depicted on the clouds over Liverpool, was seen by two residents in the Great Park at Birkenhead, for a period of forty minutes.

The straight-line distance between Edinburgh and Liverpool is about 170 miles. The coincidence of the "mirage" and the exhibition is hard to swallow.

GET-001 AN ELECTROMAGNETIC RADIATION PATTERN OVER THE OCEAN

Curtis, George D.; Undersea Technology, 5:29-30+, August 1964.

Abstract. While performing another task, scientists from the LTV Research Center discovered a unique stable electromagnetic radiation pattern over the ocean. The characteristics of the pattern, its recording, analysis, and possible causes are described. Since this natural phenomenon occurs over the ocean, further study should prove valuable to ASW and oceanography.



Comparison of five seperate runs showing the stability of the electromagnetic pattern mentioned in GET-001. Frequency used: 1740 kHz.

During a flight test program performed by LTV for another purpose, it was recognized that there exists a unique low and medium frequency electromagnetic radiation pattern over the surface of the ocean. This radiation pattern appears to be quite stable and is found as variations in the signal from radio stations. Statistical analysis showed correlation between patterns taken on consecutive runs over the same area to be as high as 0. 9 over a one-hour period. Figures 1 and 2 clearly show the repeatability of the pattern during successive runs over the same areas. Figure 1 shows two patterns (runs 2 and 5) from two broadcast stations, recorded approximately twenty minutes apart, while Figure 2 shows a set of successive runs, arranged one above the other, from one station. The day-to-day repeatability is not known.

The amplitude of the variations shown in the figures represents only the top few percent of the signal strength in the area; zero has been greatly suppressed. The equipment and experimental techniques will be explained before the "wiggles" are discussed further.

GET-001 TRANSMISSION PHENOMENA

These patterns were obtained by accurately flying back and forth over the same track over the open ocean. A pair of Collins URR—23A multiband AM receivers, modified to output their delayed AGC voltage to a seven-channel Ampex FM tape recorder (with response to DC), and a Texas Instruments dual pen recorder, were used as a sensitive field strength recording system. A dead reckoning computer, radar, careful drift corrections, and smokelights were used as navigational aids to obtain repeat accuracies of a few hundred yards, at altitudes of around 1000 feet. The Navy supplied the aircraft and crew.

The data were played back from the magnetic tape through a 0.1 cps low pass filter, onto rectilinear Sanborn charts. Large photo positives were then made from these, in which the downwind (fast) runs were enlarged slightly to match the upwind (slow) runs, thus providing a series of signal strength patterns scaled to a constant ground speed. The transparencies permit the traces to be overlaid or compared in any fashion (Figures 1 and 2) or digitized for computer analyses.

What produces this pattern? It cannot be considered to be random noise, due to the close correlation of the patterns on the different runs. This pattern is considered to be a natural phenomenon which has never been recognized before to our knowledge, but which can be duplicated by anyone using adequate equipment and techniques.

The exact cause of this radiation pattern is presently unknown. It was noticed during the program that the nature of the pattern varies with the transmitted frequencies which are used; see Figures 1 and 3. The effects are not particularly noticeable above 5,000 feet, but the pattern is generally consistent (on the same flight path) in the range from 500 to 2000 feet as shown in Figure 3. The pattern has been recorded primarily from two, clear channel, 50 KW Los Angeles broadcast stations, but is equally noticeable from other stations nearer our usual flight area, southwest of San Diego. It has also been observed, but not mathematically correlated, on the Atlantic and Gulf Coasts.

Spectral analyses were made on a number of sets of data from the original program by LCdr. L. R. Roberts of the U.S. Navy Post Graduate School. Using an IBM 704 computer, LCdr. Roberts found that a major portion of the repeatable "pattern energy" lies in the 0.005 to 0.2 cps band, which corresponds to a spacing of 3800 to 15,500 yards (approximately 10 to 50 wavelengths). Spectral bands appear above 0.02 cps. but are much more variable. It should be mentioned that the maximum length of the flight runs——20 miles——set a low frequency limit on this analysis and that field variations of even longer periods may exist.

Several explanations have been proposed for this radiation pattern. These suggestions have included:

1- Undersea or Bottom Anomalies — This is a possible explanation of the characteristic of the radiation pattern in shallow water. However, good patterns are also observed in deep water (300 fathoms and deeper).

2. Shore Line Effect-—The pattern has been observed consistently at ranges over 15 miles from islands and the continental shore line. Since 15 miles 80 wave lengths at 1 mc, the pattern should not be considered shore line effect (Reference b).

3. Clouds-—It has been suggested that the variations of the pattern are due to cloud cover. However, as stated previously, the pattern has been consistent for periods as long as one hour. This would suggest that cloud cover is not a major contributor to the radiation pattern.

4. Ionospheric Reflections——Typical patterns (Figures 1 and 2) were made mid-day in relatively high signal strength areas (order of jiv/m), 130 and

30 miles from the transmitters. Theoretically, under these conditions, ionospheric reflection should not produce even the small variations which constitute the observed pattern. However, recent work has revealed weak MF reflecting ionization between 50 and 100 KM (Reference c). It is possible that these layers or minor backscatter, could weakly reflect into the test area. Reflection from any continuous ionized layer would, however, produce a pattern symmetrical about the transmitter. This limitation has not been observed.

5. Anomalies near the transmitters which are "reflected". This seems unlikely, due to the fine structure and distance involved, but can be investigated with a three-dimension plot of a large area. The pattern occurs on station radials as well as normal thereto, and is not considered due to antenna directivity.

6. Ocean currents, temperature, salinity, etc.——The effects on radio propagation due to these variables are relatively unknown at the present time and considerable effort is required in the oceanographic field to investigate the effects of these parameters. Figure 4 shows a run over the edge of the Gulf Stream, representing a temperature difference of about 4°F at the surface, plus possible changes in waves and swells. This strongly suggests an oceanographic effect, but the repeatability of this particular pattern is not known. Zero is not suppressed so strongly in this run, made off Cape Hatteras. It is felt that (6) is the most likely cause, but no possible origin has been ruled out for further investigation.

By what mechanism could anomolies in the ocean surface produce an effect such as Figure 4 or the other patterns? When traversing an area of altered conductivity, the tilt of a vertically polarized electromagnetic wave is altered. However, this angular change would be extremely small for the change in the conductivity of sea water caused by a change in its temperature of 4°F. Now, an area of altered conductivity can also exhibit re-radiation, resembling an antenna in a lossy medium. This could give rise to a minor interference pattern. Quite possibly, the recorded signal is due to a combination of such phenomena. The program outlined below, may provide the answer.

Test Program Parameters

Frequency——VLF (Navy transmitters), 200 kc (Consol or beacon), 1 mc (broadcast station), 2 mc (Loran), and 10 mc (WWV) can be utilized. This wide range should permit separation of wave length from the size of any originating system.

Location-—Simply obtaining day-to-day comparisons over the exact same track or area should go far toward answering the problem. A grid would be flown, in at least two different locations and distances from the transmitters.

Extreme Altitudes-—Several samples of radiation patterns should be obtained at the operating altitudes of 100 feet and 5000 feet in the same area. This (even more than the rest of the program) will require the best available navigation equipment and flying skill.

Time——Comparable samples could be obtained at night. This will produce a marked change in ionosphere effects.

Most of these tests can, of course, be combined to obtain the necessary data with a reasonable amount of flight work. A more difficult problem would be obtaining oceanographic data correlatible with the airborne data.

The data can be reduced and analyzed with the techniques and computer programs used in the preliminary work. Once adequate, quantitative information is available on this phenomenon, it should not be too difficult to deduce the

origin and significance of the patterns.

It is believed that this "fixed" pattern may be novel, and has not been reported previously simply because no one in the past has made repeated traverses of the exact same track, filtered out the noise but not the pattern, adjusted runs to a constant ground speed, and compared them. It should make an interesting oceanographic problem.

Two potential correlations come to mine: (1) The Bermuda Triangle with its tales of magnetic disturbances; and (2) the wheels of light (Subsection GLW) which may originate in electromagnetic patterns of energy.

GET 002 WIRELESS ECHOES

Anonymous; Nature, 126:381, September 6, 1930.

The address given by Prof. Carl Stormer to the Royal Society of Edinburgh on Feb. 17 has now been published in the Society's Proceedings (vol. 50, p. 187). He discusses the problem of whether the 'wireless echoes of long delay' come from space outside the moon's orbit or not. In a communication to Nature of Jan. 5, 1929, he said: "the mathematical theory of the motion of electric corpuscles around a magnetised sphere shows that the chances of obtaining a well-defined toroidal space round the earth are good when the direction to the sun lies near the magnetic equatorial plane (perpendicular to the magnetic axis). " He predicted that it was very improbable that echoes would recur before the middle of February. This prediction was duly verified by several physicists. In particular, two observers in I.ndo-China observed two thousand echoes from a relatively small emitter station. The echoes came about 30 sec. after the signal and their amplitude was sometimes as great as one-third of the signal. Some of the experiments recorded prove conclusively that they were echoes. It seems as if the space outside the earth's orbit was traversed intermittently by very unstable streams of electrons. This may explain the great variety of echo times observed. It is also possible that multiple echoes may be caused by reflection between the inner walls of the toroidal space. The great variety of echoes is similar to the great variations in aurora phenomena and magnetic perturbations. If this explanation is correct, these wireless echoes give a striking proof of the corpuscular theory of aurora and a valuable method for exploring electron currents in cosmic space.

SECTION GF: FALLING MATERIAL

Falls of fish, large chunks of ice, "manna," and other materials have been reported for thousands of years. Some of these materials are unquestionably picked up and later deposited by atmospheric disturbances; other substances may have meteoric origins. Be this as it may, many falls are not easily explained, as this section will demonstrate. The subsection descriptions follow.

GFA Webs and "angel hair." Includes unusual concentrations of gossamer and web-borne spiders. Hair-like deposits left behind by geophysical phenomena.

***GFB** Falls of birds. Falls of large numbers of birds, usually dead or dying.

GFC Chemicals. Salt, sulfur, sand, dust, and other inorganic substances. Includes stones that do not seem to be of meteoric origin.

GFF Fish, reptiles, insects. Falls of any animals not normally airborne.

GFG Gelatin. Gelatinous masses and droplets——often associated with meteor-like phenomena.

***GFI** Ice falls. Large chunks of ice apparently not associated with hail-storms or other atmospheric disturbances.

GFL Leaves, hay, pollen. Unusual falls of organic material——frequently from a clear sky—and unexplained deposits, such as "manna." Pollen is sometimes associated with the colored rains described in subsection GWP.

GFT Thunderstones. Strange correlations of stones (possibly meteorites in some instances) with thunderstorms.

•This subsection not represented in Volume G2.

FALLING MATERIAL

WEBS AND "ANGEL HAIR" GFA-003

GFA-O01 RAIN OF SILK

Laine, M. ; Annual Register, 64:681, 1821.

> M. Laine, the French consul at Pernambuco, says, in a letter, dated Nov. 1, 1820, that at the beginning of the preceding month there was a shower from the sky, consisting of a substance resembling silk, of which many persons preserved specimens. This phenomenon extended to the distance of 30 leagues inland, and nearly as many off to sea. A French vessel was covered with the silky material. He has sent a specimen of it to Paris.

There is no mention of spiders, which usually shoulder the blame for such falls. Pernambuco is in Brazil.

GFA 002 SHOWER OF GOSSAMER AT SELBOURNE

Anonymous; Nature, 126:457, September 20, 1930.

> Gilbert White records ("Natural History of Selborne") that before daybreak "I found the stubbles and clover grounds matted all over with a thick coat of cobweb. . . . When the dogs attempted to hunt, their eyes were so blinded and hoodwinked that they could not proceed, but were obliged to lie down and scrape the encumbrance from their faces with their forefeet. . . . About nine, an appearance very unusual began to demand our attention—a shower of cobwebs falling from very elevated regions, and continuing, without any interruption, till the close of the day. These webs were not single filmy threads, floating in the air in all directions, but perfect flakes, or rags: some near an inch broad, and five or six long, which fell with a degree of velocity, that they were considerably heavier than the atmosphere. On every side, as the observer turned his eyes, he might behold a continual succession of fresh flakes falling into his sight, and twinkling like stars, as they turned their sides towards the sun. How far this wonderful shower extended, it would be difficult to say; but we know that it reached Bradley, Selborne and Alresford, three places which lie in a short of triangle the shortest of whose sides is about eight miles in extent." The gossamer descended even on the highest part of the downs.

This fall occurred September 21, 1741.

GFA-003 THE NOTES OF CHARLES FORT

Fort, Charles; The Fortean Society Magazine, 1:15, January 1942.

> 1820, Oct. 1. Spiders Times of Oct. 9. That over area of miles from Liverpool and especially at Wigan, fields and roads covered with a substance that was mistaken for cotton. Came down like a sheet on Wigan. Found to contain (reverse) flies so small as required a magnifying glass to make them perceptible.

GFA-004 WEBS AND "ANGEL HAIR"

GFA-004 BRILLIANT ATMOSPHERIC PHENOMENA

Anonymous; Scientific American. 1:178, September 10, 1859.

After describing a recent auroral display, the editor states:

> Mr. Merriam, of Brooklyn, in giving an account of these appearances, says:—
>
> "The auroral light sometimes is composed of threads like the silken warp of a web; these sometimes become broken and fall to the earth, and possess exquisite softness and a silver lustre, and I denominate these as the products of the silkery of the skies. I once obtained a small piece, which I preserved. "
>
> This is an entirely new idea to us, and we think that some other substance must have been picked up in a mistake for the product of the auroral loom.

Note that some other geophysical phenomena are sometimes correlated with webs or hair.

GFA-005 A RAIN OF SPIDER WEBS

Anonymous; Scientific American, 45:337, November 26, 1881.

> In the latter part of October the good people of Milwaukee (Wis.) and the neighboring towns were astonished by a general fall of spider webs. The webs seemed to come from "over the lake, " and appeared to fall from a great height. The strands were from two feet to several rods in length. At Green Bay the fall was the same, coming from the direction of the bay, only the webs varied from sixty feet in length to mere specks, and were seen as far up in the air as the power of the eye could reach. At Vesburg and Fort Howard, Sheboygan, and Ozaukee, the fall was similarly observed, in some places being so thick as to annoy the eye. In all instances the webs were strong in texture and very white.
>
> Curiously there is no mention, in any of the reports that we have seen, of the presence of spiders in this general shower of webs. It is to be hoped that some competent observer——that is, some one who has made a study of spiders and their habits-—was at hand and will report more specifically the conditions of this interesting phenomenon.
>
> Quite a number of notable gossamer showers have been reported in different parts of the world. White describes several in his history of Selborne. In one of them the fall continued nearly a whole day, the webs coming from such a height that from the top of the highest hill near by they were seen descending from a region still above the range of distinct vision.
>
> Darwin describes a similar shower observed by him from the deck of the Beagle, off the mouth of La Plata River, when the vessel was sixty miles from land. He was probably the first to notice that each web of the gossamer carried a Lilliputian aeronaut. He watched the spiders on their arrival and saw many of them put forth a new web and float away.

That spiders use their webs for parachutes there is no doubt, but are all instances of webs falling due to this cause, particularly when no spiders are present?

GFC-006 SUPPOSED METEORITE

Anonymous; American Journal of Science, 2:24:449, 1857.

We have received from Mr. Thomas Bassnett of Ottawa, Illinois, specimens of scoria, with a description of their supposed fall on the 17th of June last, about ten miles south-southwest from that place. The account of the fall, as written out by L. H. Bradley on whose farm the scoria was found, states, that the time it occurred was fifteen or twenty minutes before 2 p. m. ; the wind blew west by south. He says, "The cinders fell in a northeasterly direction in the shape of the letter V. The weather had been showery, but I heard no thunder and saw no lightning. There appeared to be a small, dense black cloud hanging over the garden in a westerly direction, or a little to the south of west. The cinders fell upon a slight angle within about three rods of where 1 was at work; there was no wind at the moment, or none perceptible. My attention was called first to the freak the wind had in the grass, and the next moment to a hissing noise caused by the cinders passing through the air. The larger ones were considerably imbedded in the earth, so much as only to show a small part of it, while the smaller ones were about one-half buried. I noticed at the time that the ground where I afterwards picked up the cinders showed signs of warmth, as there was quite a steam or fog at that particular point. I thought it singular, as the ground had been very cold previously. "

The scoria is in rounded inflated pieces, like what have been called volcanic bombs, the exterior being glassy, and the interior very cellular. They are little over an inch in the longest diameter. Color black.

The paper, called the "Sunny South, " of Aberdeen, Miss., of Sept. 17, 1857, describes a mass of lava as large as a barrel, "which fell near the farm of Mr. John Fortson, ten miles west of Aberdeen, on the 8th of July, 1856, and which excited a good deal of wonder and speculation at the time for hundreds of miles around."

The Illinois scoria is unlike any meteorite, and suggests the idea of a terrestrial origin. We know nothing about the Mississippi "lava. "

GFC-007 BODILY INJURIES FROM FALLING METEORS

Anonymous; Popular Science Monthly, 15:566-567, August 1879.

In view of the estimate made by Mr. G. J. Stoney in the paper elsewhere published in the present number of the Monthly, the following observations by Professor H. Karsten, which we take from "Die Natur," can not fail to be interesting.

The accounts recently published, of the falling of sundry small meteorites in the vicinity of men or even upon their persons, have vividly recalled to my mind another instance, as I conceive, of this phenomenon. In this case a man was wounded in such a way as to lead the bystanders to conclude that he had been wounded by a pistol-ball, though the most thorough search failed to discover any evidence confirmatory of that opinion.

The reader will perhaps remember how, according to the "Cologne Zeitung, " on August 29th of year before last, at half-past nine in the morning, a certain married couple living in the house No. 32 Neumarkt, in that city, were startled by a small stone falling through the open window into their room. "The wife

ran and picked it up——a black-gray, prismatic stone of the size of a small bean; but, as it was red-hot and burned the tips of her fingers, she quickly dropped it again. Some minutes later the husband again took it up and found it to be still so hot that he could hardly hold it in his hand. " This stone, which was immediately taken to the editor's office, was by all recognized as a meteorite.

Shortly before this, at Hanau, a boy was hit on the thumb in the open fields by a small, hot, falling stone; this, too, was supposed to be a meteorite. Unfortunately, it was never found.

At Schaffhausen, on the 2d of October, 1875, while a man was trundling a cart from the village of Beringen to Neuhausen, hence while going nearly due east, his right forearm was perforated from front to back as though by a musket-ball. The man was in the company of his brother and an acquaintance. At the moment of receiving the wound he heard a peculiar whirr as of a ball, but his companions say that they heard nothing. They all three searched high and low all around to discover the one who had fired the ball, but in vain, though the highway in which they were traveling ran straight through the open, level fields; neither was any one to be seen on the railway lying at no great distance to the right. Shortly after the occurrence the train from Neuhausen passed by. At some distance on the left are vineyards, where a few laborers were seen, but none of them had firearms, and even if they had they could not have sent a ball as far as the highway. It may be added that the wounded man is a peaceable fellow, having no enemies, so far as he knows. Besides, the missile——as is to be seen from the wound——came from the front, where no human being was to be seen on the broad, straight highway. The anterior wound was two inches inside of and two inches above the capitulum radii, and the posterior wound, which was only five millimetres in diameter, was two inches inside of and one and one third inch above the inner condyle of the ulna. The physician who attended to the case asked my opinion about this enigmatical occurrence; and, on my attributing it either to an air-gun or to a meteorite, he rejected both hypotheses. It could not have been an air-gun, he said, because no such instrument had ever been heard of in that locality; and because, even if such an instrument had been used, no one after discharging it could have concealed himself, owing to the nature of the ground, as already described. As for meteorites, no one had ever known of people being wounded by them. I was not prepared to prove my second hypothesis or to strengthen it by citing analogous instances, though authors had often recorded and described the falling of great stones in fields and through the roofs of human habitations, the bursting of falling stones in mid-air, and the scattering of the fragments. Still the hypothesis seemed to me to be not altogether groundless in the present instance, and it was strengthened by the known velocity of meteoric stones, which is on an average twelve times as great as that of a musket-ball' Then, too, the time of year and the direction of the projectile favor the opinion that the wound was inflicted by some small stray meteorite. Everybody attributed the wound to a ball from a revolver, because there was no other way to account for it. Had one of the two fellow travelers or one of the laborers in the distant vineyards been in possession of a revolver or other firearm, it would not have been easy for him to clear himself of the suspicion of having shot the man. On this ground, if not on account of its general interest, it is much to be desired that such occurrences should be investigated and published, to the end that, by bringing together and discussing the facts, light might be thrown on this interesting but as yet obscure subject.

GFC-008 [FALLING STONES]

Anonymous; Nlles' Weekly Register, 48:397, August 8, 1835.

> Vesuvius remained tranquil after the eruption of August; having then thrown out grey and red cinders similar to those of 1822; but about the middle of February, flames and small pieces of lava were thrown from the bottom of the crater, which is considerably less deep and smaller in circumference than that of 1828. This new crater, which by degrees is filling up, and is now near the top of the ridge, threatens an overthrow, and sooner or later must fall. At Marsala, on the southern coast of Sicily, on a serene day there appeared in the sky a small black cloud; which gradually extending, at last disgorged itself in a shower of stones, which broke the slates and roofs of the houses.

This report of a fall of stones is tucked into a description of Vesuvius, but the circumstances indicate that the cloud, which was small and black as seems rather typical of clouds associated with falling material, was completely divorced from the volcanic action.

GFC-009 THE RED FOGS AT CAPE VERDE

Zurcher, Frederic; Meteors, Aerolites, Storms, and Atmospheric Phenomena, C. Scribner & Co., New York, 1876.

> M. Ehrenberg believes that the name of dark or gloomy sea, given to the Atlantic by the ancients, took its rise in the phenomenon observed after the mariner has issued forth from the Straits of Gibraltar and is drawing near to the waters by Cape Verde. At the approach of the equinoxes, and during an interval that varies from thirty to forty days, there falls a very fine red powder that obscures the atmosphere and deposits itself upon the rigging of vessels. This shower of dust, known also as the red fog, extends over a sea-surface of more than a million of square miles.
>
> Showers of red dust have been frequently noted, also at different points on the Mediterranean, and in Eur.ope and Western Asia, but at irregular epochs. Near Lyons, for instance, in 1846, there fell a quantity, estimated in all at seven thousand two hundred quintals, on a surface of four hundred square miles. This dust is not composed of sand and clay alone, but also of organic substances and infusoria, which a powerful microscope renders quite visible. A sort of worm, which, along with the clay, gives color to the mixture, is so small that it requires nearly two millions of these animaleula to fill the space of a cubic inch. One thing especially remarkable is, that, in the many specimens examined by M. Ehrenberg, and collected on the Atlantic as well as in Europe, Asia Minor, and Syria, the same species have always been found. The savant in question has prepared a chart on which all the places where this dust has fallen are marked. He admits that the showers of blood mentioned in history may have been confounded with this phenomenon, since the fluid in question might well be represented by the red substance above mentioned, when the latter is moistened with water, and such an explanation of the legendary fact is too obvious to be rejected.
>
> The interesting question of the origin of these peculiar kinds of dust then occupied his attention, and led him to analyze a great many specimens of the soil collected in different parts of Africa and South America. The result showed

that nowhere on the first-named continent could species of infusoria be found the same as those discovered in the dust, while on the second they were met with near the Orinoco and Amazon Rivers.

This circumstance very forcibly struck the attention of Commander Maury, who saw that these dust-falls may serve to mark the extent of the circuit made by the aerial currents, just as bottles thrown into the sea by mariners mark the sweep of the ocean-currents.

The periodicity indicated by the appearance of this dust at Cape Verde has relation, according to Maury, to the movement of oscillation north and south of the zone of equatorial calms, a movement that carries the rainy season from point to point over the surface of America. "At the period of the spring equinox," he says, "the valley of the lower Orinoco is in its dry season; the marshes and plains in that region are converted into arid deserts; the water has, so to speak, disappeared, and the trade-winds can very readily bear away with them the dust that whirls about on these parched savannas. Six months later, at the autumnal equinox, the relative position of the zones of calm and of the trade-winds has changed. It is the greater part of the valley of the Amazon which becomes a prey to drought and which in its turn furnishes to the heavy breezes of that period of the year the organic dust that we find in the other hemisphere." (pp. 249-251)

These are not true fogs, of course, but more closely allied to pollen falls.

As an aside, the reputed muddiness of the Atlantic in ancient times was attributed to the foundering of Atlantis.

GFC-010 NINE YEARS OF CONTINUOUS COLLECTION OF BLACK, MAGNETIC SPHERULES FROM THE ATMOSPHERE

Crozier, W. D. ; Journal of Geophysical Research, 71:603-610, January 15, 1966.

Abstract. Data on the deposition of black, magnetic spherules from the atmosphere, at two stations in central New Mexico, have accumulated for the 9-year period 1956-1964. These spherules, which appear to be similar to those which I have recovered from various sedimentary rocks and to those recovered by others from ice in Antarctica and Greenland and from Paleozoic salts, are believed to be of extraterrestrial origin. The 9-year average of the annual rate of mass accretion to the earth, for spherules in the diameter range to 5 to 60 ^, was approximately 1.04 x 10 grams. The period included 2 years in which the annual infall was nearly 2. 5 x 10*1 grams, however, and therefore the long-term average remains somewhat uncertain. The size distributions show fluctuations but, in general, are similar to those previously reported. The rate of deposition decreased from 1956 to 1962, and high peaks occasionally occurred. Interesting seasonal and biennial patterns appear in the rate of deposition, and there seems to be a degree of correlation between the spherule rates and radar meteor rates, the spherule rates leading the radar rates by about 6 weeks. In 1963, high rates of spherule deposition coincided with unusually high radar meteor rates.

The point of interest here is the variation in rate of collection and its apparent dependence upon season and other factors. There may be a relationship to cycles in precipitation and other weather phenomena. See GWS.

GFF-006 SHOWERS OF ORGANIC MATTER

McAtee, Waldo L.; Monthly Weather Review, 45:217-224, May 1917.

McAtee's survey is classic and is quoted in full except for the numerous footnotes. Where a footnote identifies the source of a direct quotation in the original McAtee article, it has been placed directly after the quotation.

Introduction

The idea of organic matter and particularly of living things raining down from the sky, on first thought, is hard to entertain. There have been recorded in all periods of historic time, however, showers of one kind or another of animals and plants or their products——showers of hay, of grain, of manna, of blood, of fishes, of frogs, and even of rats. In ages past, these phenomena, actual or supposed, were all given supernatural significance; the blood rains terrorized the people, the manna rains inspired prayers of thanks——they were miracles. In latter days, the tendency among intellectuals who have given the matter no particular attention, has been to assume that since preternatural explanations had usually been invoked (and they certainly were incredible) therefore the showers themselves probably never occurred.

However, so many wonderful things occur in nature that negation of any observation is dangerous; it is better to preserve a judicial attitude and regard all [authentic] information that comes to hand as so much evidence, some of it supporting one side, some the other, of a given problem.

The evidence that counts the most is that which comes from those we have learned to respect and trust. I may say that two small bits of testimony as to living things falling in rain, given me by my father, and by my friend, Mr. A. N. Caudell, of the United States Bureau of Entomology, did more than all I had ever read to arouse my interest in the phenomena of organic showers. Mr. Caudell relates that at his former home in Oklahoma, on one occasion after a brief shower during an otherwise dry and hot period, numerous earthworms were found on the seat of an open buggy standing in the yard. Mr. Caudell's mother was reminded by this occurrence that years before, in their former home in Indiana, a live minnow was found after a rain in water held by the hollow in the top of a chopping block. The experience of my father that bears on this subject is that when in North Dakota some years ago on coming indoors during a rain he found several earthworms on the brim of his hat. Here are facts vouched for by persons in whom I have every confidence, proving to a certainty that living animals do rain down.

How potent are such small phenomena, once fixed in the mind as well authenticated, to give one faith in the larger ones; but, on the other hand, how important is the conviction that some extensive, some really great happening of the same class really has occurred. When, therefore, I came upon the statement by the famous French scientist, Francis Castlenau, that he had seen fishes rain down in Singapore in such numbers that the natives went about picking them up by the basketful, I was ready to believe almost all the tales, both great and small, relating to showers of organisms.

And why should we not believe them? Surely not from any doubt as to the capacity of the wind to lift up, to transport, and to drop again, at more or less distant places, objects of the character and size usually mentioned as falling in organic showers. All strong winds have some lifting powers; we see papers carried into the air, blown hither and thither, and sometimes carried for long distances. Sheets of paper have been identified as falling at places 20 to 50

miles distant from their starting point. Through experiences, sometimes saddening ones, most of us have learned that the wind can very dexterously lift and transport such objects as hats, and I have known of a silk hat being taken from a dignified gentleman's head as he was walking in front of the Post Office Department in Washington and carried up, up, and away over the Star Newspaper Building (10 stories high). In the same city during the thunder squall of July 31, 1913, tin roofs were torn from many houses and blown into the streets.

These are things which straight blowing winds can do, but when winds begin to whirl, their lifting and carrying capacity increases enormously. The little dust whirls we see seem inoffensive things, but they have surprising power. *I* saw one travel down a row of shocks in a cornfield, lift every one of them, and scatter the stalks to the four quarters, doing in a minute work it would take a man a day to do or undo. Of course this whirl was larger than those we frequently see on hot summer days, but whirlwinds, waterspouts, dust storms, and tornadoes are essentially the same thing differing principally in dimensions. Wind whirls which may be said to be practically artificial in origin develop surprising power. Thus Theodore Dwight, of Stockbridge, Mass., states that those created by the burning of wood piled in a clearing had sufficient force to lift trees 6 to 8 inches in diameter to a height of 40 to 50 feet.

All wind whirls are characterized by a more or less strong inflow of air along the surface from all directions to the base of the whirl, where the inflowing currents ascend. The gyratory velocity of a tornado may be as much as 310 miles per hour. This would give at the earth's surface an effective force in moving an object of about 300 pounds for each square foot of surface exposed to the wind. The velocity of the ascending currents also runs high, but if put at 176 miles per hour would yield a lifting power of more than 90 pounds to the square foot. That these forces are actually exerted is shown by some of the remarkable doings of tornadoes. By the tornado at Beauregard, Miss., April 22, 1883, the solid iron screw of a cotton press, weighing 675 pounds, was carried 900 feet. During the tornado of April 16, 1875, at Walterborough, S. C., a piece of timber 6 inches square and 40 feet long, weighing 600 pounds, was carried a distance of 440 yards, and a chicken coop, 4 by 4 feet and 75 pounds in weight, was transported 4 miles. In the tornado at Mount Carmel, III., June 4, 1877, a piece of tin roof was carried 15 miles and a church spire 17 miles.

These examples are quite as marvelous as some of the seemingly miraculous showers recorded of old. The children of Israel believed in their manna because they gathered it with their own hands and ate of it, but surely their credulity would not have stood the test had some prophet told them that in years to come, in a land across the sea, chickencoops and church spires would rain down from the skies.

There is then, we must admit, no reason for general suspicion towards the accounts of organic showers. Like other records, they must be inspected and the good sifted from the mass. We may separate at once certain classes of alleged organic showers as spurious.

A. Spurious Showers

Insect larvae. — The rains of insect larvae that have been investigated have proved to be merely the appearance in large numbers on the surface of the ground or upon snow of the larvae of soldier beetles (Telephorus), or sometimes caterpillars, which have been driven from their hibernating quarters by the saturation of the soil by heavy rains or melting snow.

Ants.——Accounts of showers of ants have usually been founded on incursions of large numbers of winged ants, which of course need no assistance from

the elements to follow out their habit of swarming forth periodically in immense numbers.

Honey; sugar.——Showers of honey and of sugar are popular names for what scientists know are exudations of certain plants, or of plant lice which feed on a great variety of plants and whose product is often known also as honey-dew.

Grains.—Showers of grain, usually considered miraculous, have in most cases been determined to be merely the accumulation by washing during heavy rains of either the seeds or root tubercles of plants of the immediate neighborhood.

Black rain.——Black rain is due to the precipitation from the atmosphere by falling water of soot, or in some cases of black dust. These showers are of interest, however, as illustrating the carrying power of the wind; a rain of soot observed in Ireland and over the Atlantic Ocean to the westward is pretty definitely known to have been carried by the wind from Wales. The showers of mud resulting from the precipitation of dark-colored dust or dirt are closely related to the organic showers discussed further on, as the material must have been derived from the earth's surface, transported and deposited in the same way, and in fact it is probable that all such rains bring with them some proportion of small organisms. In the case of a black snow, observed in New York in 1889, it was found that the color was due to "finely divided earth and vegetable mould. " In this case it is certain that small organisms were included among the debris, for it would be impossible for the wind to sweep up enough vegetable mould to discolor a snowfall without at the same time taking up a considerable number of spores, seeds, fruits, and small animals.

Blood rains.——The most frequently reported showers that are spurious, at least in name, are the so-called blood rains. In all times the phenomena going under this name have frightened the people and have been taken as portents of terrific calamities. One of the famous plagues of Egypt was a bloody rain which prevailed throughout the whole land, continuing three days and three nights. Homer and Virgil both allude to blood rains, and, in fact, the general subject of preternatural rains was a favorite with the older writers.

But scientific investigation has done away with the element of mystery in these phenomena and has explained, with the others, the rains of blood. Some blood rains have been found to be the meconial fluid ejected by large numbers of certain lepidoptera simultaneously emerging from their chrysalides; other red rains are due to the rapid multiplication in rain pools of algae and of rotifers containing red coloring matter; "red snow" results from the presence of similar organisms. But in no case have they rained down, except in the sense that their spores or eggs have at some time been transported, probably by the wind. The precipitation of moisture furnishes favorable conditions for their rapid development and multiplication.

There are several summaries of information relating to the anciently recorded showers of miscellaneous matter. Among them is that of Valentin Alberti, "Dissertatio historica physica de Pluvia prodigiosa", Leipzig, 1674; one by P. J. Hartmann, published as an appendix to the Miscellanea Curiosa * * * Academiae Imperialis Leopoldinae * * * Jena, 1689; another by J. C. Haebler, entitled "Dissertatio de pluviis prodigiosis, " published at Erfurt in 1695, and also one by C. G. Ehrenberg in 1847 (Abh. Kgl. Preuss. Akad. Wiss. Berlin.).

For modern bibliographies covering the subject of organic showers, see: Fassig, O. L. Bibliography of Meteorology, United States Signal Service, Showers of Miscellaneous Matter, Part II, 1889, pages 367-391, and Stuntz, S. C., & Free, E. E. Bibliography of Eolian Geology, Bulletin 68, United States Bureau of Soils, 1911, pages 174-263.

Manna.——An account of manna "rains" certainly pertains to the discussion of showers of vegetable matter, for the substance manna consists of lichens of the genus Lecanora, but in none of the numerous recorded instances of manna "rains" is there any direct evidence that the substance really fell from the sky. These lichens form, small, round bodies that are easily blown over the surface of the ground and accumulate in depressions; they are very buoyant also and hence easily drifted into masses during the run-off of rain water. Manna "rains" have not occurred except in countries where these lichens are common, and as for statements of their falling down upon roofs or upon people, or for any other proofs that they really rained down, I have seen none.

B. True Showers

Red rains; dust.——Other red rains are caused by the bringing down in rain water of atmospheric dust of a reddish color. This hue usually is noticed in rain falling in southern Europe at a time when the air is charged with sirocco dust. The composition of this dust has been extensively investigated and it has been found to contain spores, pollen grains, confervoid algae, diatoms, infusoria, and rotifers. In 50 samples of sirocco dust from various parts of Italy pollen, spores, etc., were found in every one. In sirocco dust collected at Lyons, Ehrenberg claims to have found 111 different species of infusoria, and the total number of organisms enumerated by him from samples of such dust is 320. In the Lyons instance organic forms made up one-eighth of the entire mass of the dust. Since various estimates place the amount of sirocco dust in a fall at from 5-1/2 to 9 tons to the square mile, it will be seen that a fall of a ton of microscopic organisms per square mile is within the bounds of possibility.

It is not only the hot and dry sirocco that is laden with dust containing organisms, for indeed they are in the air everywhere at all times. The researches of MM. Miquel and Boudier in France, particularly have elucidated the nature of atmospheric dust. The atmosphere always is charged with a large number of organic entities. The vegetable constituents are chiefly bacilli and the spores of cryptogams, as of fungi, lichens, mosses, and algae. There are also hairs of plants, fibers of cotton, flax, and hemp, pollens of every form, and starch grains. The animal remains include epithelial cells, hairs, shreds of feathers, bits of down and wool, scales of lepidoptera, and the eggs of infusoria. The quantity of suspended matter in the air is high in summer and low in winter, and less at high altitudes than in lower areas nearer the source of the bodies found.

Special forms of aeroscopeshave been devised to collect samples of atmospheric dust. In one form described by Mr. Hubert Airy, were caught in the city of London, the following things additional to those just names: Living mites, entomostraca, and diatoms.

It appears, therefore, that a great variety of small organisms or their spores are present in the air at all times, that they are freely carried about by the winds, and are constantly being precipitated either in dust or in falling moisture. The possibilities for the distribution of these minute forms are practically unlimited, for dust clouds travel indefinite distances. In the United States a dust storm and mud shower was observed on the same day in Illinois, New York, Pennsylvania, and New Jersey. This shows transport of the material over a third of the breadth of the United States, if indeed all of it did not come from the western plains. A dust cloud a thousand, perhaps two thousand miles in length was observed at sea by J. Milne when 200 to 400 miles distant from the coast of China, from whose loess plains it was probably derived. This dust contained shreds of plants. At times of great volcanic activity, dust clouds have encircled the world. There is, therefore, no limit to the distribution of

atmospheric dust, and therefore probably none to that of the minute organisms that are one of its constant components.

Showers of plants and invertebrates.

Pollen falls, sulphur rains.——Pollen of various plants, as previously noted, is one of the most common constituents of atmospheric dust; for instance, Miquel found that there are often a thousand pollen grains to each cubic meter of air. But pollen deserves more extended notice because it is really showers of pollen that have been so often reported as showers of sulphur. The yellow color suggested sulphur; pollen, especially of pine, is highly inflammable, the imagination supplied the smell of brimstone, and superstition jumped at the conclusion that the devil had been busy. The occasional phosphorescent appearance of pollen falls at night also has encouraged preternatural speculations.

The following is extracted from an account of a pollen shower in England in early June, a fall of fine yellow dust which coated the surface of rain water in barrels and pools, was taken by the uneducated for a fall of sulphur. It was said by the imaginative to smell "awful like brimstone" and to presage the end of the world. Examination of the dust under a microscope at once showed it to be the pollen of pine. Another writer adds:

As this mystery, if it is not explained, may prove serious to the nervous, superstitious, or credulous part of the community, we may as well add that at this season districts in the neighborhood of fir (Pinus sylvestris) plantations run the risk of a thorough dusting of this powder if there is the slightest breeze, as the cones of the young Scots fir are thickly coated with yellow powder or pollen, which will give out a blinding saffron cloud on the slightest disturbance. f Nature, 20:267]

The appearance of a conspicuous movement of pollen has been well described by Dr. D. P. Thomson.

On the afternoon of June 11, 1847, the wooded part of Morayshire appeared to smoke, and for a time fears were entertained that the fir plantations were on fire. A smart breeze suddenly got up from the north and above the woods there appeared to rise about 50 columns of something resembling smoke, which was wreathed about like waterspouts. The atmosphere now calmed and the mystery was solved, for what seemed smoke was in reality the pollen of the woods. flntroduction to Meteorology, 1849]

The ease with which pollen is taken up into the air together with the prodigal profusion with which it is produced make it easy to understand the frequency of the so-called sulphur rains. In March 1879, several instances of yellow rain or snow occurred in the United States. Prof. W. H. Chandler of Lehigh University, South Bethlehem, Pa., writes that during Saturday night, March 16, 1879, there was a slight fall of snow in that section and on Monday morning when the snow had melted, a yellow deposit was found covering the ground more or less. Upon examining the deposit, it was found to be the pollen of pine trees. The United States Signal Corps observer at New Orleans, reports light showers on the 17th of the same month, and states that "a peculiar feature of the rain was its yellow color, which was due to large quantities of the pollen of the cypress tree floating in the atmosphere." The United States Signal Corps observer at Lynchburg, Va., forwarded on March 21, 1879, a sample of the yellow deposit which had fallen with the rain the preceding night and " * * *it was found to consist * * * entirely of the characteristic triple-grained pollen of the pine." A pollen shower at Pictou, Nova Scotia, in June, 1841, was so heavy that bucket-Ms were swept up on a ship. This material was entirely the pollen of pine trees. As showing how far pollen may be transported by the wind, it is noted

that "A shower of this kind fell at Lund at the south of Sweden, which M. Agardh (Nova Acta, 12) found to contain the pollen of Pinus sylvestris or Scotch fir, borne on the wind from a forest about 35 miles distant."

Hay.—The vegetable substance, which, after pollen, figures most frequently in the accounts of actual showers of organic matter, is hay. This should not be surprising, since the material is comparatively light and is available at the time of year when wind whirls are most frequent. The first step in the development of a shower of hay was observed by Prof. F. E. Nipher, who describes a whirlwind that picked up hay and carried it in the form of an inverted cone about 200 feet high and 150 feet in diameter at the top. The whirl was followed for about half a mile when it disappeared over a hill. The complete phenomenon, on a small scale, is described as follows by Sir Francis Galton:

We had a curious sight * * * yesterday (July 26, 1891). It was a dead calm, but in a field just below the garden * * * the hay was whirled up high into the sky, a column connecting above and below, and in the course of the evening we found great patches of hay raining down all over the surrounding meadows and our garden. It kept falling quite four hours after the affair. [Nature, 44-294]

On June 30, 1892, a large quantity of hay was taken up by a whirlwind at Nether Priors, Essex, England, and fell at Belchamp, about 3 miles to the north. In two other cases noted, one in London, the other in Ireland, the hay was seen floating at a great height in the atmosphere and then to fall.

Wheat.——In my introductory remarks I stated that most of the so-called showers of grain were spurious. However "in 1804 * * * a real rainfall of wheat took place in Andalusia, which had been carried by a hurricane across the Straits of Gibraltar, from a threshing floor at Tetuan."

Meteoric "paper. "——A substance which has fallen from the sky, and has been called "meteoric paper, " was proved in one case at least to be vegetable matter of terrestrial origin. Ehrenberg who investigated the case says "On the 31st of January, 1687, a great mass of paper-like, black substance fell with a violent snowstorm * * * near the village of Rauden in Courland." Some of the substance was preserved and it was 152 years later that Ehrenberg examined it and found it to consist "of a compactly matted mass of Conferva crispata, traces of Nostoc and of about 29 * * * species of infusoria." This material was undoubtedly the crusts of dried algae which form on the surface of the ground exposed by the evaporation of the water of shallow ponds. This paper-like substance could easily be lifted up by the wind and carried a long distance.

Jelly or "flesh."——Manna is the bread of organic showers; but what is the meat? Showers of flesh have often been recorded and they have proved to be precipitations of a glairy substance, which upon partial drying formed enough of a skin on the outside to induce people to call it flesh. When found fresh, this material has been compared to butter. Probably most if not all of it is the material known as zooglea formed on the surface of water where bacteria are actively multiplying. The substance known as zoogen or zoiodin is probably the same. An extensive shower of such jelly-like material occurred in Bath County, Ky., in 1876, and was referred to as the dried spawn of fishes or of some batrachian.

Such spawn really has rained down also, if we may believe the account of M. Moreau de St. Mery, relating to an observation in San Domingo.

From November, 1785, to the 5th of May, 1786, there was experienced a terrible drought. The last day, viz, May 5, 1786, there fell during a strong east wind, in several parts of the city of Port au Prince * * * a great quantity of black eggs, which hatched the following day. M. Mozard preserved about 50 of these small animals in a flask half full of water, where they shed their

skins several times. They resembled tadpoles. [A Naturalist's Sojourn in Jamaica, 1851]

Other jelly rains have proved to consist of the egg masses of midges, and of colonies of infusoria. A shower of the latter is described as follows by L. Jenyns in his article on a so-called storm of insects at Bath, England:

There had been a sudden squall of wind before there came a heavy rain, and my idea is that these organisms must have been lifted up by the force of the wind, acting in a gyratory manner, from some shallow pool in the neighborhood. * * * A boy at the station first noticed them (that is, the spherical masses in which the organisms were grouped) falling on his coat * * *; as the rain fell more heavily the platform * * * was covered with them. [Zoologist, 6:2286]

Insects.——The popular designation of these infusoria as insects of course was due to the very wide misuse of this term. I have noted previously that the alleged showers of insect larvae also were not genuine, but there have been apparently a few real rains of insects. Two which occurred in Germany are described as follows:

At Szentes, August 14, between 9 and 10 p. m. a deep-black cloud suddenly appeared in the evening sky. Soon thereafter began a downpour, not of rain, but of winged insects, which in a few minutes covered the ground a foot deep. At St. Catherine a d. Lamming (Obersteiermark) on the 10th and 11th of August, insect rains also occurred, which while not so remarkable, still were very annoying. The insects were in part small neuropteroids and in part winged ants. [Meteorol, Ztschr., 18:426]

Accounts of three other showers which have been gleaned from French publications are circumstantial, and clearly show sustained transport of insects by the wind and their falling from the skies after the manner of rain;

Toward the end of May, M. L. Aude, * * * while returning from Mortagne to Herbiers, was caught in a violent storm from the northeast which, during a heavy rain, covered his conveyance with a multitude of Gryllus. The wind was cold and the Orthoptera falling in the midst of the rain appeared lifeless. These * * * are all in the larval state and are Gryllus domesticus of authors. [Bui. Soc. ent. France, p. 96, 1858]

Rey de Morande in describing a shower of insects and spiders in Haute-Savoie, says:

On the night of January 29-30 [1869?], about 4:30 a. m., with a violent gust of wind which soon ceased, snow fell until day, and in the morning there were found on this snow a large quantity of living larvae. * * * (The temperature for some days before had been very low.) * * * They appeared to be, for the most part, larvae of Trogosita mauritanica, which are common in old trees in the forests in southern France. There were found also larvae of a little moth * * * probably Stibia stagnicola. This shower of insects and spiders at an altitude of 1,000 to 1, 200 meters, can not be explained except by transportation by a violent wind from central or southern France.

M. Tissot, * * * who observed the phenomenon, adds, that in November, 1854, several thousands of insects, mostly living were thrown down by a violent wind in the vicinity of Turin. Some were larvae and some adult and all appeared to be of a species of hemiptera that had never been collected except on the isle of Sardinia. [Bui, hebd., Assoc. sci. de France, 5:242]

Molluscs.——Before leaving the consideration of invertebrates we may note that: "A shower of mussels, some weighting [sic] about 2 ounces, fell during a severe storm, on the 9th of August, 1834, in the United States. The following year another shower of molluscous animals, Bulimus truncatus, took place at Montpelier [France].

Falls of vertebrate organisms

The fall of vertebrate animals from the skies like rain is, of course, the most interesting of all the showers of organic matter, and——it must be admitted—the hardest to believe. Yet there cannot be the slightest doubt that there are genuine phenomena of this character, though perhaps not so numerous as the recorded instances. These occurrences, if observed by man, naturally make profound impressions and in the olden times especially, the tales of showers of fishes and the like were improved by each teller, so that soon they reached the stage of the unbelievable.

Frogs, toads.——1 quote only one of the older writers, Athenaeus, who flourished about 200 A. D. He is the author of a polyhistorical work called the "Deipnosophists," in which he quotes about 800 authors, whose works he consulted at the Alexandrian Library, 700 to whom would have been unknown, except for the fortunate preservation of Athenaeus' work. In a chapter entitled "De pluvius piscium, " he says:

I know also that it has very often rained fishes. At all events Phenias, in the second book of his Eresian Magistrates, says that in the Chersonesus it once rained fish uninterruptedly for three days; and Phylarchus in his fourth book, says that people had often seen it raining fish, and often also raining wheat, and that the same thing had happened with respect to frogs. At all events Heraclides Lembus, in the 21st book of his history, says: "In Paeonia and Dardinia, it has, they say, before now rained frogs; and so great has been the number of these frogs that the houses and the roads have been full with them; and at first for some days the inhabitants, endeavoring to kill them, and shutting up their houses endured the pest; but when they did no good, but found that all their vessels were filled with them, and the frogs were found to be boiled up and roasted with everything they ate, and when besides all this they could not make use of any water, nor put their feet on the ground for the heaps of frogs that were everywhere, and were annoyed also by the smell of those that died, they fled the country." [The Deipnosophists or Banquet of the Learned, Book XV, pt. 2, pp. 526-527]

For numbers of frogs and the far reaching effects of their fall this tale can scarcely be surpassed, but it will be well to recount some later instances, especially some of the more circumstantial ones. Holinshed informs us that in Great Britain——

Frogsfell in Angueshire during the time of Agricola. Frogs were reported to have descended, during the summer of 1846 over the Humber, upon the decks of vessels in the river and on the coast near Killinghome lights. [Thompson, David P. ; Introduction to Meteorology, pp. 164-165, 1849]

A later accounts recites that——

During the storm that raged with considerable fury in Birmingham (England) on Wednesday morning, June 30 [1892], a shower of frogs fell in the suburb of Moseley. They were found scattered about several gardens. Almost white in color, they had evidently been absorbed in a small waterspout that was driven over Birmingham by the tempest. [Symon's Meteorological Magazine, 32:107]

Several notices have from time to time been brought before the French Academy of showers of frogs having fallen in different parts of France. M. Duparque states in a letter that——

In August, 1814, after several weeks of drouth and heat, a storm broke one Sunday about 3:30 p. m., upon the village of Fremon, a quarter league from Amiens. This storm was preceded by bursts of wind so violent that they shook the church and frightened the congregation. While traversing the space separating the church from presbytery, we were soaked, but what surprised

me was to be struck on my person and my clothing by small frogs. * * *A large number of these small animals hopped about on the ground. On arriving at the presbytery, we found the floor of one of the rooms in which a window facing the storm had been left open covered with water and frogs. [L'Institut, 2:354]

Showers of toads seem to be more common in some regions than those of frogs. I have seen accounts of 13 different occurrences of the kind in France. A French scientist M. Mauduy, curator of natural history at Poitiers, had personal experience with two such showers, which he narrates briefly as follows:

On the 23d of June, 1809, during a hot spell, I was caught in a rain storm in which with the very large drops were mixed little bodies the size of hazelnuts, which in a moment, covered the ground, and which I recognized as little toads. * * * The second occasion, occurred in August, 1822, during a stormy and very hot period. I was again surprised by a heavy shower of large drops mixed, as was the other, with little toads, some of which fell on my hat. This time the animals were the size of walnuts. I found that I was more than a league distant from any brook, river, or marsh. fL'Institut, 2:409]

A considerable discussion of the subject of rains of toads was carried on in 1834 in the French scientific magazine from which I have quoted. I cite two more bits of testimony by eye witnesses, one of which has been widely reproduced.

M. Heard, writes:

In June, 1833, I was at Jouy near Versaille. I saw toads falling from the sky; they struck my umbrella; I saw them hopping on the pavement, during about 10 minutes in which time the drops of water were not more numerous than the toads. The space upon which I saw the multitude of these animals was about 200 fathoms. fL'Institut, 2:353]

M. Peltier in his oft-copied statement says:

In support of the communication of Col. Marmier, I cite an incident I observed in my youth; a storm advanced upon the little village of Ham, Department of the Somme, where I lived, and I observed its menacing march, when suddenly rain fell in torrents. I saw the village square covered everywhere with little loads. Astonished by this sight, I held out my hand and was struck by several of the reptiles. The dooryard also was covered; I saw them fall upon the slate roof and rebound to the pavement. * * * Whatever the difficulty of explaining the transport of the reptiles, I affirm, without doubt the fact which made such a profound impression upon my memory. [L'Institut, 2:346-347]

The most remarkable account of a shower of toads, that I have seen, so far, is the following:

In the summer of 1794 M. Gayet was quartered in the village of Lalain, Department du Nord, * * * near the territory which the Austrians, then masters of Valenciennes, had flooded with water from the Scarpe. It was very hot. Suddenly, at about 3 o'clock in the afternoon, there fell such an abundance of rain that 150 men of the grand guard, in order not to be submerged, were obliged to leave a large depression in which they were hidden. But what was their surprise when there began to fall on the ground all about a considerable number of toads, the size of hazelnuts, which began to jump about in every direction. M. Gayet, who could not believe that these myriads of reptiles fell with the rain, stretched out his handkerchief at the height of a man, his comrades holding the corners; they caught a considerable number of toads, most of which had the posterior part elongated into a tail, that is to say, in the tadpole state. During this rain storm, which lasted about half an hour, the men of the grand guard felt very distinctly on their hats and on their clothing the blows struck by the falling toads. As a final proof of the reality

of this phenomenon, M. Gayet reports that after the storm the three-cornered hats of the men of the guard held in their folds some of the reptiles. [L'Institut, 2:354]

Fish.——For reports of the falling of frogs and toads from the skies, we have been far afield, for the very good reason that I have not found any cases reported for the United States. But for fishes, there are several reports. Before giving these accounts, allow me to introduce a few statements that tend to show how fishes get started on the aerial journeys that terminate in fish rains.

To show the tremendous power of waterspouts, we may quote M. Oersted's declaration that "At Christiansoe a waterspout emptied the harbour to such an extent that the greater part of the bottom was uncovered. " Naturally under such circumstances fishes and any other organisms in the water may change their habitat very abruptly. Waterspouts have been observed to accomplish the comparatively insignificant tasks of emptying fish ponds and scattering their occupants.

A prodigy of this kind is recorded to have occurred in France, at a town some distance from Paris, during a violent storm. When morning dawned, the streets were found strewed with fish of various sizes. The mystery was soon solved, for a fish pond in the vicinity had been blown dry, and only the large fish left behind. [Reess' Cyclopedia]

So, during a storm on December 28, 1845, at Bassenthwaite, England, fish were blown from the lake to dry land.

Proceeding now to the United States records, Mr. Thomas R. Baker states that——

During a recent thunderstorm at Winter Park, Fla., a number of fish fell with the rain. They were sunfish from 2 to 4 inches long. It is supposed that they were taken up by a waterspout from Lake Virginia, and carried westward by the strong wind that was blowing at the time. The distance from the lake to the place where they fell is about a mile. [Science, 21:335]

In the Monthly Weather Review for June, 1901 (p. 263), is the note "Mr. J. W. Gardner, voluntary observer at Tillers Ferry, S. C., reports that during a heavy local shower about June 27 [1901] there fell hundreds of little fish (cat, perch, trout, etc.) that were afterwards found swimming in the pools between the cotton rows."

In all, I am acquainted with four records of falls of fishes in the United States, two in South America, eight in Great Britain, two in France, and six in India and neighboring countries: These are all well vouched for, or fairly modern and circumstantially related instances. The older, chiefly traditional, records would make a longlist.

One of the most ancient records of fish having fallen from the atmosphere in Great Britain is the following: About Easter, 1666, in the parish of Stanstead, which is a considerable distance from the sea, or any branch of it, and a place where there are no fish ponds and rather scarcity of water, a pasture field was scattered all over with small fish, in quantity about a bushel, supposed to have been rained down from a cloud, there having been at the time a great tempest of thunder, rain, and wind. The fish were about the size of a man's little finger. Some were like small whitings, others like sprats, and some smaller, like smelts. Several of these fish were sold publicly at Maidstone and Dartford. A shower of herrings is recorded to have taken place near to Loch Leven, in Kinross-shire, about the year 1825; the wind blew from the Frith of Forth at the time, and doubtless the fish had been thereby carried from the sea across Fifeshire to the place where they were found. In 1828,

similar fish fell in the county of Ross, 3 miles distant from the Frith of Dingwall. On the 9th of March, 1830, in the Isle of Ula, in Argyleshire, after a heavy rain, numbers of small herrings were found scattered over the fields; they were perfectly fresh, and some not quite dead. On the 30th of June, 1841, a fish measuring 10 inches in length, with others of smaller size, fell at Boston; and during a thunderstorm, on the 8th of July, in the same year, fish and ice fell together at Derby. [Thompson, D. P.; Introduction of Meteorology, p. 103, 1849]

A convincing statement of personal experience with a rain of fishes is that of John Lewis, of Abderdare, who says that while working, February 9:

I was startled by something falling all over me——down my neck, on my head, and on my back. On putting my hand down my neck I was surprised to find they were little fish. By this time I saw the whole ground covered with them. I took off my hat, the brim of which was full of them. * * * They covered the ground in a long strip about 80 yards by 12 yards, as we measured afterwards. * * * We gathered a great many of them * * * and threw them into the rain pool, where some of them now are. * * * It was not blowing very hard, but uncommon wet. * * * The person who took this testimony adds that he secured about 20 of the little fish, some of which were 4 and 5 inches long. A number of these fishes were exhibited for several weeks in the aquaria house of the Zoological Society in the Regent's Park, London. [Tomlinson, Charles; The Rain-cloud and the Snow-storm, pp. 193-194]

The accounts of rains of fishes in South America are by Alexander von Humboldt, whose language relating to them is as follows:

When the earthquakes, which precede every eruption in the chain of the Andes, shake with mighty force the entire mass of the volcanoes, the subterranean vaults are opened and emit at the same time water, fishes, and tufa-mud. This is the singular phenomenon that furnishes the fish Pimelodes cyclopum, which the inhabitants of the highlands of Quito call "Prefiadilla, " and which was described by me soon after my return. When the summit of the mountain Carguairazo to the north of Chimborazo and 18,000 feet high, fell, in the night between the 19th and 20th of June, 1698, the surrounding fields, to the extent of about 43 English square miles, were covered with mud and fishes. The fever which raged in the town of Ibarra seven years before had been ascribed to a similar eruption of fishes from the volcano Imbaburu. [Annuals of Philosophy, 22:130]

There are several well authenticated reports of falls of fish in India, and this has given rise to the belief that the phenomenon is more frequent there than elsewhere. This may be true on account of the favoring circumstances of extensive river flood plains, numerous shallow water tanks, a fish fauna rich in shoal water forms, and a hot whirlwind-breeding climate. Certainly the description of fish rains in that part of the world are numerous, specific, and astonishing as to the magnitude of the phenomena.

One of the oldest reports, brief but with a humerous touch, I quote first. It is by Lieut. John Harriott, who says:

In a heavy shower of rain, while our army was on the march a short distance from Pondicherry, a quantity of small fish fell with the rain to the astonishment of all. Many of them lodged on the men's hats.* * * They were not flying fish, they were dead and falling from the well-known effect of gravity; but how they ascended or where they existed I do not pretend to account. I merely relate the simple fact. [Struggles through Life, pp. 141-142, 1809]

A very valuable account of a shower of fishes is that by J. Prinsep, editor of the Journal of the Asiatic Society of Bengal. He writes:

The phenomenon of fish falling from the sky in the rainy season, however

incredible it may appear, has been attested by such circumstantial evidence that no reasonable doubt can be entertained of the fact. I was as incredulous as my neighbors until I once found a small fish in the brass funnel of my pluviometer at Benares. I have now before me a note of a similar phenomenon, on a considerable scale which happened at the Nokulhatty factory, Zillah Dacca Jedalpur, in 1830.

Mr. Cameron, who communicated the fact, took the precaution of having a regular deposition of the evidence of several natives who had witnessed the fall made in Bengalee and attested before the magistrate; the statement is well worthy of preservation in a journal of science. * * * The shower of fish took place on the 19th of February, 1830, in the neighborhood of the Surbundy factory, Feridper (p. 650). [Journal of the Asiatic Society of Bengal, 3:650-652]

There are depositions of nine eye witnesses, of which I quote two:

Shekh Chaudari Ahmed, son of Mutiullah, inhabitant of Nagdi, relates in his deposition: "I had been doing my work at a meadow, when I perceived at the hour of 12 o'clock the sky gather clouds, and gegan to rain slightly, then a large fish touching my back by its head fell on the ground. Being surprised I looked about, and behold a number of fish likewise fell from heaven. They were saul, sale, guzal, mirgal, and bodul. I took 10 or 11 fish in number, and I saw many other persons take many. "

Shekh Suduruddin, inhabitant of Nagdi, was called in and declared in his deposition saying: "On Friday, at 12 o'clock p. m., in the month of Phalgun * * * when I was at work in a field, I perceived the sky darkened by clouds, began to rain a little and a large fish fell from the sky. I was confounded at the sight, and soon entered by cottage, which I had there, but I came out again as soon as the rain had ceased and found every part of my hut scattered with fish; they were boduli, mirgal, and nouchi, and amounted to 25 in number. " [Journal of the Asiatic Society of Bengal, 3:650-652]

The large number of fishes that may rain down is illustrated by another Indian instance which was reported as follows:

On the 16th or 17th of May last a fall of fish happened in monon Sonare, pergunna Dhata Ekdullah, Zillah Futteppur. The zemindzry of the village have furnished the following particulars which are confirmed by other accounts. About noon, the wind being from the west, and a few distant clouds visible, a blast of high wind, accompanied with much dust, which changed the atmosphere to a reddish yellow hue came on; the blast appeared to extend in breadth about 400 yards. * * * When the storm had passed over, they found the ground south of the village to the extent of two bigahs strewed with fish, in number not less than three or four thousand. The fish were all of the Chalwa species (Clupea cult rat a), a span or less in length, and from 1-1/2 to 1/2 seer in weight; when found they were all dead and dry. Chalwa fish are found in the tanks and rivers of the neighborhood; * * * the nearest water is about half a mile south of the village. [Journal of the Asiatic Society of Bengal, 3:367]

For the number of fishes that fell this account is not surpassed, but for all-around interest, and credulity inspired by the name of its distinguished author, the testimony of Francis de Castelnau, mentioned at the beginning of this paper, is supreme. The note is entitled "Shower of Fishes; earthquake at Singapore," and was published in 1861.

We experienced here an earthquake at 7:34 p.m., February 16, that lasted about two minutes; it was followed by hard rains, which on the 20th, 21st, and 22d became veritable torrents. The last day at 9 a.m. the rain redoubled in fury, and in a half hour our inclosed plot became a sea of water. * * *

At 10 o'clock the sun lifted and from my window I saw a large number of Malays and Chinese filling baskets with fishes which they picked up in the pools

of water which covered the ground. On being asked where the fishes came from, the natives replied that they had fallen from the sky. Three days afterwards, when the pools had dried up, we found many dead fishes.

Having examined the animals, I recognized them as Clarias batrachi, Cuvier and Valenciennes, a species of catfish which is very abundant in fresh water in Singapore, and the nearer Malayan Islands, in Siam, Borneo, etc They were from 25 to 30 centimeters long, and therefore adult.

These siluroids, the same as Ophicephalus, etc , are able to live a long time out of water, and to progress some distance on land, and I thought at once that they had come from some small streams near by; but the yard of the house I inhabited is inclosed in a wall that would prevent them entering in this manner. An old Malay has since told me that in his youth he had seen a similar phenomenon. [Comptes Rendus, 52:880-881]

Other vertebrates.——Showers of vertebrates other than frogs, toads, and fishes are rare indeed. It was recorded in 1873 that a shower of reptiles fell Minnesota, and from the description it is evident the creatures were larvae of a salamander, probably of Amblystoma tigrinum. The Monthly Weather Review for May, 1894 (p. 215) states that during a severe hailstorm "at Boving, 8 miles east of Vicksburg, Miss., a gopher turtle 6 by 8 inches and entirely incased in ice fell with the hail. "

This is a most remarkable occurrence, but what shall we say of a shower of birds, in which hundreds dropped dead in the streets of a Louisiana city? In the Baton Rouge, La., correspondence of the Philadelphia Times, some time in 1896, it is stated that——

On Friday morning last early risers in the little capital [Baton Rouge, La.] witnessed a peculiar sight in the shape of a shower of birds that fell from a clear sky, literally cluttering the streets of the city. There were wild ducks, catbirds, woodpeckers, and many birds of strange plumage, some of them resembling canaries, but all dead, falling in heaps along the thoroughfares, the singular phenomenon attracting many spectators and causing much comment.

The most plausible theory as to the strange windfall is that the birds were driven inland by the recent storm on the Florida coast, the force of the current of air and the sudden change of temperature causing death to many of the feathered creatures when they reached Baton Rouge. Some idea of the extent of the shower may be gathered from the estimate that out on National Avenue alone the children of the neighborhood collected 200 birds. [San Jose Gazette, November 4, 1896]

This seems clearly not to have been a case of migrants becoming confused by city lights, nor killing themselves by flying against obstacles, mishaps which rather frequently occur to bird travelers. The phenomenon of migration among mammals gives rise to the only story of a shower of those animals that I have seen. It is given by Charles Tomlinson, who writes.

In some countries rats migrate in vast numbers from the high to the low countries; and it is recorded in the history of Norway that a shower of these, transported by the wind, fell in an adjacent valley.

I have not seen the original of this tale, but it may have been prompted by the appearance, in large numbers, of lemmings which frequently migrate in hordes in Scandinavia. It is possible, of course, that during one of these migratory movements some of the animals were transported by a violent wind and precipitated as "a shower of rats. "

C. Wind as a Distributing Agent.

We have reviewed instances of the rain-like fall of various animal and plant bodies, of pollen, of hay, of diatoms, algae, rotifers, of insects, frogs,

toads, fishes, salamanders, turtles, birds, and rats. It remains to inquire what significance, if any, these phenomena have for the distribution of living things upon the earth.

Vertebrates.——In the case of vertebrates distribution by wind transport must be of practically no importance. Mammals and birds thus snatched up by the wind, if carried any distance, arrive dead. Batrachians also often are killed, and if not, usually must be carried for short distances only; the chances are also that they will reach an unfavorable environment and perish for that reason. Fishes, most of all, are fated to fall where they can not survive, and their inability to live long out of water strictly limits the possibilities of their deriving advantage by wind transport. In addition, it must be remembered that in all these groups instances of their being carried by the wind are really rare. All in all, we must conclude that the wind is a very unimportant factor in the distribution of vertebrate animals.

Plant seeds.——In the case of most seed-producing plants, although hundreds of species have seeds modified for wind transport, it has not been shown that they are especially successful in making rapid strides in distribution. Kerner says:

The distance to which specially adapted seeds may be carried by the wind is considerable, but in ordinary course is not attained. * * * Among the numerous species of fruits and seeds obtained from snow fields and glaciers high in the Alps not one was derived from a distant district.

Volgler, who made a special study of the means of distribution of alpine plants, found that instances of spread by the wind to distances of from 3 to 40 kilometers were not rare, while "transport of seeds * * * to great distances, even hundreds of kilometers * * * is possible, but in the actual distribution of plants plays a minor role."

Spores, etc——When we come to consider, however, the distribution of plants and animals that have j spores, eggs, statoblasts, or other minute but resistant resting stages, it is apparent that winds are their most important means of spread.

The United States Bureau of Entomology has shown that winds are important in the distribution of mites (McGregor, E. A., & McConough, F. L., Dept. Agr. Bui. 416, 1917, pp. 31-32), and the gipsy-moth (Collins, C. W., Dept. Agr. Bui. 273, 1915). Small larvae of the last-named pest were found to be carried 13-1/2 miles by ordinary winds. For a typical exposition of the agency of wind in distributing, fungus spores, see Journ. agric research, Washington, March, 1915, 3:493-525.

Reflect what opportunities are offered to the wind in every dry basin left by the evaporation of shallow pools. The drying of the water stimulates all the organisms to produce their encysted forms. The bottom is crusted with matted algae bearing their own spores or oogonia, resting stages which long retain their vitality and which are ready at any time to profit by wind transport. Among the algae there may be flagellates, bacteria, diatoms, the spores of aquatic mosses, of horsetails, of club mosses, and quillworts, and the minute seeds of rushes. There may be also cysts of protozoa, gemmules of fresh-water sponges, the statoblasts of bryozoa, and the eggs of worms, leeches, Crustacea, insects, and molluscs, all of which may be minute enough to be carried readily by the wind and resistant enough to survive the process. Untold numbers of these reproductive bodies may be gathered up by the wind and carried long distances. This goes far to explain the extremely wide, often cosmopolitan distribution of fresh water microorganisms.

It is not only aquatic organisms that have spores suitable for carriage by the wind, but also a long series of terrestrial ones including bacteria, algae,

fungi, mosses, liverworts, ferns, and club mosses. Dust-like seeds as those of orchids, broom-rapes, pyrolas, live-for-evers, etc., are almost as well adapted to wind transport as are spores. Perhaps the best illustration that can be given of the potency of the wind in distributing these plants is the part it played in the revegetation of the isolated volcanic island Krakatoa from which all life was extirpated by the 1883 eruption of almost unparalleled violence. From 16 to 30 per cent of the phanerogams established on Krakatoa 25 years after the catastrophe of 1883 were carried there by winds, as were all of the ferns (16 species) and lower cryptogams, almost without exception (more than 30 species). Between 49 and 63 per cent of its flora, therefore, is wind-borne. The first recolonization of the island in 1886 was entirely by wind-distributed species as algae, bacteria, diatoms, liverworts, mosses, and ferns.

The distribution of spores and other light reproductive cells does not depend on sporadic gusts of wind that suddenly pick up a quantity of these objects to later drop them as showers of organisms; there seem to be a certain number of them always in the atmosphere. In fact, aeroscopes reveal a steady fall of atmosphere. In fact, aeroscopes reveal a steady fall of atmospheric dust, including minute organisms, that must be a far more important element in the distribution of such life than the more impressive but sporadic showers.

D. Conclusion.

It would appear, therefore, that the more spectacular the shower of organic matter the less its importance in the distribution of life. The rains of larger animals have attracted much attention and excited wonder, but in many cases the animals have been dead; in others they were doomed to die because of falling in an unsuitable environment. Not often are all the conditions propitious for the species to secure a new foothold.

The unobtrusive, but steady and widespread movement of minute eggs and spores by the atmosphere, however, is of great importance in distribution because these organic bodies are adapted to survive such transport; their numbers are so great and their dispersal so wide that some of them will necessarily fall in favorable places. The chances are, in fact, that every suitable environment will be populated. So far as mere preservation of species is concerned, we see here, as in other phases of viological investigation, the superiority of the pigmy over the giant, of insignificance over conspicuousness, of passivity and adaptability over strenuous effort. "Blessed are the meek, for they shall inherit the earth. "

GFF-007 SHOWER OF PERCH — SUNSETS

Stewart, John A.; Knowledge, 4:396, December 28, 1883.

Being a constant reader of your valuable journal, I enclose the cutting from today's Edinburgh Scotsman, of rather a peculiar phenomenon witnessed in Airdrie, viz., a shower of live perch, last Saturday morning, Dec. 15. Now, perch never, or rarely, swim near the surface of the water, and, if drawn up by a whirlwind, it must have been an extra strong current to have drawn them from deep water.

GFF-008 FISH, REPTILES, INSECTS

GFF-008 SHOWER OF FISH

Anonymous; Annual Register, 101:14-15, 1859.

If anyone has entertained doubts as to the possibility of this phenomenon, his hesitation will be put to rest by a well-certified occurrence at Mountain Ash, Glamorganshire. At 11 a. m. of the 9th of February, during a heavy rain, a stiff gale blowing from the south, a very large number of small fish were precipitated upon the fields and housetops at that place. The phenomenon was witnessed by a great number of persons: the Rev. Mr. Roberts, curate of St. Peter's, Carmarthen, and the Rev. John Griffith, the Vicar of Aberdare and Rural Dean, made inquiries on the spot, in order to preserve the facts of this curious occurrence. The following is the testimony of John Lewis, a sawyer, who was the principal witness:-

"On Wednesday, February 9, I was getting out a piece of timber, for the purpose of setting it for the saw, when I was startled by something falling all over me——down my neck, on my head, and on my back. On putting my hand down my neck I was surprised to find they were little fish. By this time I saw the whole ground covered with them. I took off my hat, the brim of which was full of them. They were jumping all about. They covered the ground in a long strip of about 80 yards by 12, as we measured afterwards. That shed (pointing to a very large workshop) was covered with them, and the shoots were quite full of them. My mates and I might have gathered bucketsful of them, scraping with our hands. We did gather a great many, about a bucketful, and threw them into the rain pool, where some of them now are. There were two showers, with an interval of about ten minutes, and each shower lasted about two minutes or thereabouts. The time was 11 a. m. The morning up-train to Aberdare was just then passing. It was not blowing very hard, but uncommon wet; just about the same wind as there is to-day (blowing rather stiff, and it came from this quarter (pointing to the S. of W.). They came down with the rain in 'a body like.'"

Mr. Griffith collected 18 or 20 living specimens of the unexpected visitants and transmitted them to Professor Owen. The three largest were four inches long. Some, which died after capture, were fully five inches in length.

GFF-009 A FISH STORM

Anonymous; Niles' Weekly Register. 52:356, August 5, 1837.

Dr. Wood, a naturalist, relates the astonishing fact, that after a thunder-storm at Louisville, on the 21st ultimo, he saw the puddles of water collected in the streets and the commons, swarming with a species of psicatory tribe, varying in weight from 10 to 3 dwts. which not without doubt he ranks with the genus Exocetus, although the pectoral fins are not united with the sides quite near enough to the spinal membrane to be the true Elrolans. He further observes that by placing them in a glass jar of water between himself and the light of a taper, he found the body to be transparent and void of veins or arteries. Only two parts of the body contained blood vessels visible to the naked eye. The air vessels covered the whole interior of the sides and back. Whether they ascended in the clouds in spawn and there attained their present size, or whether they were drawn up in that perfection, he does not decide.

"Piscatory" was spelled incorrectly in the original article.

GFF-010 FISHES FALLEN FROM THE SKY

Jochelson, Waldemar; Science, 58:516, December 21, 1923.

The Yukaghir, living on the Siberian tundra between the Kolyma and Alaseya rivers, told me that the sky, regarded by them as a beneficent deity, to supply men with food flings fishes to the earth. When fish appear in the lakes in great numbers, the Yukaghir say that they have fallen from heaven. They know well enough that fish develop from spawning, but they say that fish originally had been and continue to be sent by the deity. When asked how they knew fish fall from the sky, the Yukaghir asserted that they often found living pike (Esox lucius) and a river species of salmonidae, called cheer (Coregonus nasutus), in dry places. Evidently, said the Yukaghir, it followed that these fish in falling from heaven failed to reach the water. I explain this phenomenon in the following way: The majority of polar lakes are connected by small rivulets which the fish follow when passing from one lake to another for spawning. In the course of the passage the fish jump over obstructions formed by stones and grass hillocks. In the summer when the rivulets run completely dry in places, the migrating fish may find themselves caught on dry land.

GFF-011 [FALLS OF FISH AND SHELLS]

Anonymous; Edinburgh New Philosophical Journal, 1:186-188, 1826.

5. Shower of Fishes in Argyleshire.——"The rare occurrence of such falls renders them so remarkable, as to be remembered after long intervals of time, and even after every circumstance connected with them is forgotten. When any phenomenon is not considered in its relation to any particular cause, few will attend to its possible relations to preceding events; and fewer still will esteem it of such importance as to treasure up the observations which they might have happened to make, even although these might be of great importance, in illustrating the nature and causes of the circumstances observed.

It is thus, that, though the testimony of many has enabled me to ascertain, that a shower of herring-fry fell in Lorn, about the year 1796, yet I have not met with any who could inform me of the particulars concerning it.

In the same district, and near the same place, on a small eminence above Melford House, a shower of herring fell in 1821, in every respect so large and good, that the tenants by whom they were found were induced to send some of them to their landlord, then residing in Edinburgh. In regard to the state of the weather, I could learn no more than that it was exceedingly boisterous; while the hill on which they were found is exposed to the south-west wind, which blows along Loch Melford, an arm of the sea in which herrings are frequently found; and, as far as I know, the only one on this quarter in which the fly is commonly and successfully used in fishing them.

In the month of March 1817, strong gales of wind from the north were experienced in Appin. Upon the evening of the second day of their continuance, rain fell in abundance; and next day being very warm and sultry, some children observed a large quantity of herring-fry scattered over a moss a little to the north-east of the ferry of Shien. There might have been about three barrels or more of these, and measuring from 1-1/2 to 3 inches in length. Now, the place in which they were found is only about 300 yards north of Lochcreran, an arm

of the sea running east and west, from which several supposed the fry must have been raised. The wind, however, being from the north, renders this a seeming impossibility; and it may, perhaps, be more safely concluded, that they must have been ejected from the Linnhe Loch, another arm of the sea, extending south-west and north-east, about three miles north of the place in which they were found. A range of moorland, about 300 feet above the level of the sea, intervenes; but it is easier to suppose the cause which originally elevated these fry to be so powerful as to carry them this height and distance, than that they should obtain a course contrary to the general body of the air. They exhibited no appearance of being bruised by the fall, nor was there any thing which could induce them to believe that water had fallen at the same time. "——Letter Rev. Colin Smith of Appin to the Editor.

6. Shower of Herrings in Galloway.——"Macchirmore, or the Head of the Macchirs, for indeed there is not much white ground above it, pertains to Dunbar of Macchirmore. It is situate upon the east side of the river of Cree, one mile distant to the south from the town of Monnygaffe; and here is the first ford of the water of Cree, except that betwixt Kirkmabreck and Wigton, of which more hereafter. This ford is five miles, or thereby, in recta linea, to the northward distant from Wigton. In the moors of this parish of Monnygaffe, not many years since, at a place called La Spraig, not far distant from the water of Munnach, but sixteen miles distant from the sea, there fell a shower of herring, which were seen by creditable persons, who related the story to me. Some of the said herring were, as I am informed, taken to the Earl of Galloway's house, and shown to him. "——Andrew Symson's Large Description of Galloway, 1684. Edinb. 1823, p. 31. ' "

7. Shower of Herrings in Kinross-shire.——Mr. Arnot informs me, that, about a year ago, a shower of herrings fell near Loch Leven; it came in the direction of the Frith of Forth, and the herring are conjectured to have been blown out of the water of the Frith, and carried by the wind across Fifeshire, to the place where they were found, in the vicinity of Loch Leven.

8. Shower of Shells in Ireland.——"I send you another instance of a shower of shells, which fell at Monastereen, in the county of Kildare, a few days ago. At this time the tides were remarkably high, and the sea exhibited marks of unusual disturbance. I regret that I can send one only of these shells.''

GFF-012 [FALL OF HERRING FRY]

Anonymous; Gentleman's Magazine, 2:2 :462, May 1828.

April 21. As Major Forbes Mackenzie, of Fodderty, in Strathpeffer, co. Ross, was traversing a field on his farm, he was surprised to find a considerable portion of the ground covered with herring fry, of from three to four inches each in length. The fish were fresh and entire, and had no appearance of being dropped by birds——a medium by which they must have been bruised and mutilated. The only rational conjecture that can be formed of the circumstance is, that the fish were transported thither by a water-spout——a phenomenon that has before occurred in this county, and which is by no means uncommon in tropical climates. The Frith of Dingwell lies at a distance of three miles from the place in question; but no obstruction occurs between the field and the sea——the whole is a. level strath or plain——and water-spouts have been known to carry even farther than this. Major Mackenzie has forwarded a small quantity of the fish to the secretary of the Northern Institution.

GFG-007 PWDRESER

Hughes, T. McKenny; Nature, 83:492-494, June 23, 1910.

Here follows one of the classic accounts of "star jelly" or "gelatinous meteors."

In my boyhood I often lived on the coast of Pembrokeshire. Wandering about with my gun I was familiar with most natural objects which occurred there. One, however, which I often came across there, and have seen elsewhere since, greatly roused my curiosity, but I have not yet met with a satisfactory explanation of it.

On the short, close grass of the hilly ground, I frequently saw a mass of white, translucent jelly lying on the turf, as if it had been dropped there. These masses were about as large as a man's fist. It was very like a mass of frog's spawn without the eggs in it. I thought it might have been the gelatinous portion of the food disgorged by the great fish-eating birds, of which there were plenty about, as kingfishers eject pellets made up of the bones of the fish they eat, or that possibly there might be some pathological explanation connecting it with the sheep, large flocks of which grazed the short herbage. But the shepherds and owners of the sheep would have known if such an explanation were admissible. They called it "pwdre ser, " the rot of the stars.

Years afterwards I was in Westmorland, on the Geological Survey, and again not unfrequently saw the "pwdre ser. " But I now got an addition to my story. Isaac Hindson, of Kirkby Lonsdale, a man whose scientific knowledge and genial personality made him a welcome companion to those who had to carry on geological research in his district, told me that he had once seen a luminous body fall, and, on going up to the place, found only a mass of white jelly. He did not say that it was luminous. I have never seen it luminous, but that may be because when it was light enough to see the lump of jelly, it would probably be too light to detect luminosity in it.

Then, in my novel reading, I found that the same thing was known in Scotland, and the same origin assigned to it, for Walter Scott, in "The Talisman, " puts these words in the mouth of the hermit:- "Seek a fallen star and thou shalt only light on some foul jelly, which in shooting through the horizon, has assumed for a moment an appearance of splendour. " I think that I remember seeing it used elsewhere as an illustration of disappointed hopes, which were "as when a man seeing a meteor fall, runs up and finds but a mass of putrid jelly, " but I have lost the reference to this passage.

Thus it appeared that in Wales, in the Lake District, and in Scotland, there existed a belief that something which fell from the sky as a luminous body lay on the ground as a lump of white jelly.

I asked Huxley what it could be, and he said that the only thing like it that he knew was a nostoc. I turned to Sachs for the description of a nostoc, and found that it "consists, when mature, of a large number of moniliform threads interwoven among one another and imbedded in a glutinous jelly, and thus united into colonies of a specifically defined form.... The gelatinous envelope of the new filament is developed, and the originally microscopic substance attains or even exceeds the size of a walnut by continuous increase of the jelly and divisions of the cells."

All the nostocs, however, that I have had pointed out to me have been of a green or purplish or brown-green colour, whereas the "pwdre ser" was always white, translucent in the upper part, and transparent in the lower part, which appeared to occur among the roots of the grass, as if it grew there. Moreover,

the mass was much larger than a walnut, in fact, would generally about fill a half-pint mug.

The only reference I can find from which it would appear that the writer was describing a nostoc is the passage in Dryden and Lee (1678).

"The shooting stars end all in purple jellies." In the following note, appended to this passage, it is clear that the writer thought that the jelly-like matter found where shooting-stars had seemed to fall, was white.

Note. - "It is a common idea that falling stars, as they are called, are converted into a sort of jelly. Among the rest, I had often the opportunity to see the seeming shooting of the stars from place to place, and sometimes they appeared as if falling to the ground, where I once or twice found a white jelly-like matter among the grass, which I imagined to be distilled from them; and thence foolishly conjectured that the stars themselves must certainly consist of a like substance."

Poets and divines carry the record of this curious belief far back into the seventeenth century.

Suckling (1541) says:-

"As he whose quicker eye doth trace
A false star shot to a mark't place
Do's run apace,
And, thinking it to catch,
A jelly up do snatch."

Jeremy Taylor (1649):-

'Tt is weaknesse of the organ that makes us hold our hand between the sun and us, and yet stand staring upon a meteor or an inflamed gelly."

Henry More (1656):-

"That the Starres eat . . . . that those falling Starres, as some call them, which are found on the earth in the form of a trembling gelly, are their excrement."

Dryden (1679):-

"When I had taken up what I supposed a fallen star I found I had been cozened with* a jelly."

William Somerville (1740):-

"Swift as the Shooting Star that gilds the night
With rapid transient Blaze, she runs, she flies;
Sudden she stops nor longer can endure
The painful course, but drooping sinks away,
And like that falling Meteor, there she lyes
A jelly cold on earth."

Several old writers, however, while agreeing as to the mode of occurrence of the "pwdre ser," and recognising the widespread belief that it was something which fell from the sky and was somehow connected with falling stars, have tried to find some more commonplace and probable explanation of the phenomenon, and most of them refer it to the stuff disgorged by birds that had fed on frogs or worms.

Merrett (1667), for instance, in his work on meteors and wandering lights, says:-

"Sequuntur Meteora, ignita, viz. Ignis fatuus, the Walking fire, or Jack of the Lantern, Castor and Pollux, Helena, Ignis lambens. Draco, Stella cadens: Est substantia quaedam alba et glutinosa plurimis in locis conspicua quam nostrates 'Star-fain' nuncupant, creduntq; multi originem suam debere stellae cadenti hujusq; materiam esse. Sed Regiae Societati palam ostendi solummodo oriri ex intestinis ranarum a corvis in unum locum congestis, quod aliis etiam ejusdem societatis viri praestantissimi postea confirmarunt."

The Rev. John Morton, of Emmanuel College (1712), is, however, the only one who, so far as I can ascertain, ever tried any experiments with the view of finding out what it really was. He set some of it on the fire, and when he had driven off all the watery part, there was left a film like isinglass, and something like the skins and vessels of animal bodies. He records many observations as to its time and mode of occurrence; for instance, he says that "in 1699-1700 there was no star-gelly to be found about Oxenden till a wet week in the end of February, when the shepherds brought me above thirty several lumps." This and other observations suggest that it is a growth dependent upon the weather, &c. On the other hand, he says that he saw a wounded gull disgorge a heap of half-digested earth-worms much resembling star-jelly, and that Sir William Craven saw a bittern do the same in similar circumstances.

The Hon. Robert Boyle, 1744, explaining how clammy and viscous bodies, such as white of egg, are reduced to a thin and fluid substance, says:-

"And I remember, I have seen a good quantity of that jelly, that is sometimes found on the ground, and by the vulgar called a star-shoot, as if it remained upon the extinction of a falling star, which being brought to an eminent physician of my acquaintance, he lightly digested it in a well-stopt glass for a long time, and by that alone resolved it into a permanent liquor, which he extols as a specifick to be outwardly applied against Wens."

Pennant seems to have supposed that its origin was that suggested by Morton, for in his description of the winter mew he says:- "This kind (i. e. the Coddy Moddy or Winter Mew) frequents, during winter, the moist meadows in the inland parts of England remote from the Sea. The gelatinous substance, known by the name of star shot, or star gelly, owes its origin to this bird or some of the kind, being nothing but the half digested remains of earth-worms, on which these birds feed and often discharge from their stomachs."

I have found it commonly near the sea, but have never seen any trace of earth-worms or other similar food in it.

Here, then, we have a well-known substance which may be of different origin in different cases, respecting the general appearance of which, however, almost all accounts agree. The variety of names under which it is known point to its common and widespread occurrence, e.g. pwdre ser, star-slough, star shoot, star shot, star-gelly or jelly, star-fall'n.

We have in every name, and in every notice in literature, a recognition of the universal belief that it has something to do with meteors, yet there does not appear to be any evidence that anybody ever saw any luminosity in the jelly. Nor has anybody seen it disgorged by birds, except in the case of those two wounded birds where some half-digested gelatinous mass was thrown up. Nor has anyone watched its growth like nostoc from the ground.

In 1908 I was with my wife and one of my boys on Ingleborough, where we found the"powdre ser" lying on the short grass, close to the stream a little way above Gaping Ghyl Hole. For the first time I felt grateful to the inconsiderate tourist who left broken bottles about, for I was able to pack the jelly in the bottom of one, tie a cover on, and carry it down from the fell. I sent it, with the sod on which it appeared to have grown, to my colleague, Mr. E. A. Newell Arber, with a brief sketch of my story and the reason why I thought it of interest. Mr. Arber reported that it was no nostoc, and said that he had sent it over to Mr. Brookes, in the Botany School, who reported that it was a mass of bacteria.

That is the end of my story, but I confess I am not satisfied. The jelly seemed to me to grow out from among the roots of the grass, and the part still tangled in the grass was not only translucent but quite transparent.

What is it, and what is the cause of its having a meteoric origin assigned to it? Has anyone ever seen it luminous?

GFG-008 GELATIN

Should anyone come upon it I should be very grateful if they would send it, and the sod on which it is found, to the Botany School at Cambridge, with a label indicating what the parcel contains, so that it may be attended to before decay has perhaps obscured important features.

GFG-008 PWDRE SER

Free, Edward E. ; Nature, 85:6, November 3, 1910.

On my return from a field season beyond the reach of periodicals, I have just seen, for the first time, Prof. McKenny Hughes's article on "Pwdre Ser" in Nature of June 23, and the correspondence relating thereto in the succeeding numbers. It may interest your readers to know that a substance of this sort was found by Mr. Rums Graves (at one time lecturer on chemistry in Dartmouth College) at Amherst, Mass., on August 14, 1819, and "by him identified with a luminous meteor which had been seen to fall at that spot on the previous evening. His report of the occurrence appeared in the American Journal of Science, vol. ii., pp. 335-7, 1820. The mass of jelly was circular, about 8 inches in diameter and about 1 inch thick. It was of a bright buff colour, and covered with a "fine nap similar to that on milled cloth. " The interior was soft, of an insufferable odour, and liquefied on exposure to the air. Some of this liquid was allowed to stand in an open glass for a few days, when it had entirely evaporated, leaving only a small quantity of a "fine ash-coloured powder without taste or smell," which effervesced strongly with sulphuric acid, but not with nitric nor hydrochloric .

Mr. Graves's account was noted by Arago in the Annal. de Chimie, vol. xix. , pp. 67-9 (1821), who quoted also several similar occurrences cited in earlier chronicles. It is probable, of course, that Mr. Graves was mistaken in his identification, that the meteor actually fell at some other point, and that the jelly was confused therewith only because no other unusual substance was found at the point where the meteor was supposed to have fallen. Mr. Graves himself considered that there was "no reasonable doubt that the substance found was the residuum of the meteoric body, " but the evidence which he states is hardly satisfactory to the modern, more critical inquirer.

It seems probable that these jellies are, in general, Plasmodia of some form or forms of Myxomycetes, and that their common identification with falling stars may have its basis in the frequent recurrence of this error into which Mr. Graves seems to have been led. It is well known that visual estimates of the distance of falling stars are almost invariably far too low. If, then, an untrained observer of a meteor goes next morning to the near-by place where he thought he saw the body fall, and finds there no unusual body excepting one of these Plasmodia, the jelly and the meteor are almost sure to be associated in his mind. Especially is this probable, since the Plasmodia, in general (at least in my experience), have the appearance of having fallen on the grass rather than of having grown there.

The original account published in the American Journal of Science can be found in GFG-004.

GFL-003 ACCOUNT OF METEORIC STONES, MASSES OF IRON, AND SHOWERS OF DUST, RED SNOW, AND OTHER SUBSTANCES, WHICH HAVE FALLEN FROM THE HEAVENS, FROM THE EARLIEST PERIOD DOWN TO 1819

Anonymous; Edinburgh Philosophical Journal, 1:221-235, October 1819.

Chapter III of this report covers "other substances" and some of the more interesting items are reproduced below.

B. C. 472, Nov. 5 or 6. A great fall of black dust, probably at Constantinople, during which the heavens seemed to burn. —Procopius, Marcellinus, Theophanes, &c. (p. 233)

Middle of the 9th century, red dust, and matter like coagulated blood, fell from the heavens. —-Kazwini, Elmazen. (p. 233)

1110. A burning body fell in the Lake of Van in Armenia, and made its waters blood red. The earth was cleft in several places. —Matth. Eretz. (p. 233)

1416. Red rain fell in Bohemia. —Spangenberg.

1548, Nov. 6. A red substance like coagulated blood, fell with a meteor, probably in Thuringia. —-Spangenberg. (p. 233)

1560. On the day of Pentecost, red rain fell at Embden and Louvaine.——Fromond.

——Dec. 24. A meteor and red rain fell at Lillebonne.—Natalis Comes. (p. 234)

1618, Aug. A shower of blood, stones, and a meteor, fell in Styria.——DeHammer. (p. 234)

1718, March 24. Gelatinous matter fell, with a globe of fire in the Isle of Lethy in India.——Barchewitz. (p. 234)

1796, March 8. A viscous matter fell along with a meteor in Lusatia. It had the colour and odour of dried brown varnish, and is supposed by Chladni to consist of sulphur and iron. Gilbert's Annal, lv. (p. 234)

1813, March 13 and 14. Much red dust, red snow, and red rain, fell in Calabria, Tuscany, and Friuli, at the time of the fall of meteoric stones at Cutro. Snow and hail, of a yellow-red colour, fell over all Tuscany, with a north wind. Snow, of a brownish-yellow colour, fell at Bologna, the wind being south-west.——Bibl. Brit. Oct. 1813, and April 1814. According to Sementini, this dust contained,

Silex	.33	Chrome	.1
Alumina	.15-1/2	Carbon	.9
Lime	.11-1/4	Loss	.15-3/4
Iron	.14-1/2		100

It is probably significant that meteors are often seen before a fall of material.

GFL-004 A RAIN OF SOLID MATTER

Anonymous; Journal of the Franklin Institute, 90:11-12, 1870.

Cosmos contains a notice of a remarkable rain of yellowish matter which fell at Genoa, during the morning of the 14th of February, 1870. The informa-

tion is communicated by M. G. Boccardo, director of the Technical Institute, of that place, and Prof. Castellani, who together made an examination of it. The quantitative analysis gave as result:

Water	6.490
Organic matter	6.611
Siliceous and Argillaceous sand (the latter in small quantity)	65.618
Oxide of Iron	14.692
Carbonate of Lime	8.589
	100.00

The microscope revealed the presence of numerous spherical or irregularly ovoidal globules, of the color of cobalt-blue, corpuscles resembling the spores of Permospore: corpuscles of a pearly color with concentric zones, greatly resembling grains of starch, fragments of Diatomacea, &c.

This report is typical of the "yellow rains."

GFL-005 YELLOW RAIN

Ernst, A.; Nature, 4:68, May 25, 1871.

The following notice will perhaps be of some interest to the readers of Nature. In December 1870, after a heavy rain at Rosario de Cacuta (New Granada), a great many small round specks of a yellow clayish substance were found on the leaves of plants that had been exposed to the rain. A sample of this substance was sent to Dr. A. Rojas, of this town, who forwarded it to me in order to examine it under the microscope. It proved to be composed almost entirely of a species of Triceratium, and another of Cosmarium, which must have been carried away by a violent storm from their lacustrian abodes.

Cosmarium is a type of fresh-water algae. See the comments on this observation in GFF-006.

GFL-006 [FALL OF YELLOW POLLEN]

Anonymous; Nature, 66:157, June 12, 1902.

Several correspondents have sent to the daily papers accounts of the fall of a yellow powder on June 1 and 2 during a thunderstorm. At Great Yeldham, in Essex, and at Langport, Somerset, this yellow sediment was found after the storm had subsided, and was thought to be sulphur. Mr. C. Turner has, however, pointed out in the Times that the substance supposed to be sulphur is in reality the pollen from pine trees. This is often produced in large quantities and has many times been mistaken in country places for "showers of sulphur."

GFL-007 THE MANNA OF THE ISRAELITES

Teesdale, M. J.; Science Gossip, 3:229-233, 1897.

Many reports tell of manna "falling" from the skies, but usually this means that the manna was found one day where it did not exist the day before. That manna exists, one cannot doubt. Indeed, the following report tells of several varieties. The question is: "Does it actually fall out of the sky?"

In a recent botanical work of authority occurs the following passage: "It should be mentioned that the manna sent to the Israelites on their journey out of Egypt to the Holy Land is identical with the lichen described here and figured on page 695, and the older view that the manna of the desert was the sap of a tamarisk (Tamarix gallica-mannifera) exuded under the influence of a parasite is without any foundation. "

The lichen thus positively asserted to be identical with the manna of Scripture (see Exodus xvi. and Numbers xi.) is described in the same work as consisting of three species, spread over an enormous region in South-West Asia and extending as far as the south-east of Europe and the north of Africa. It was first observed by the celebrated naturalist and traveller, P. S. Pallas, in 1769, in the deserts of Tartary, and was named Lecanora esculenta, Pallas (fig. Ia); it is also known as Sphaerothallia esculenta, Nees. "It forms, " says Professor Kerner, "thick, wrinkled and warted crusts on the stones, preferably on small fragments of limestone; the outer colour of the crust is a greyish yellow, while on breaking it appears as white as a crushed grain of corn. " The Algerian specimens in the Cryptogamic Department of the Natural History Museum are smaller than the Asiatic, and are of a reddish colour, probably borrowed from the soil on which they are rolled about, as hereafter described. "As they get older the crusts become rent, and separate either partially or wholly from their substratum, to which they were only lightly attached by root-like fringes. When they first become loosened the edges of the detached portion become somewhat rolled back. The rolling then continues, and ultimately the loosened piece forms an elliptical or spherical warted body, with a very much contracted central cavity. . . . As a rule the hole is filled with air, and when dried the pieces weigh very little. It is easy to see that the loose portions will be rolled about by the wind, and that a storm will sometimes sweep them up from the ground and carry them hither and thither through the air. In rainy seasons the manna-lichen is also washed by rivulets into the depressions in the Steppes, and in some years in such quantities that they form heaps a span high, and one man can in a day collect four to six kilo-grammes (about 12, 000 to 20, 000 pieces, varying in size from a pea to a hazel-nut). This is especially the case in the Steppes region and in the high lands of South-West Asia, where the manna-lichen is used as a substitute for corn in years of famine, being ground in the same way, and baked into a species of bread. . . . . All the great so-called rains of manna, of which news has come from the East to Europe, occurred at the beginning of the year, between January and March, i. e. at the time of the heaviest rains. "

In an article in the "Gardeners' Chronicle" for September, 1849, it is stated that this lichen springs up with great rapidity after rain on the Khirgiz Steppes and in Central Asia, and it is mentioned that accounts had then recently been received of the fall——as it were from the skies——of prodigious quantities in one night in the neighbourhood of Erzerum, in Armenia. It is added that Parrot brought specimens collected in the beginning of 1828 which were said to have descended from the skies in some districts of Persia, and to have covered the

ground to the depth of five or six inches. Gobel analysed these, and believed them to have been carried by electrical winds from distant localities. He believed it to be Parmelia esculenta (another synonym of Lecanora esculenta), a native of the Steppes and the districts between the Caspian and Aral Seas. In 1829, during the war between Persia and Russia, there was a great famine in Orumiah, south-west of the Caspian. One day, during a violent wind, the surface of the country was covered with a lichen which "fell down from heaven." The sheep immediately attacked and eagerly devoured it, which suggested to the inhabitants the idea of reducing it to flour and making bread of it, which was found to be good and nourishing.

In the spring of 1841 there was an astonishing fall of the same substance near Lake Van, in the east of Asia Minor. It covered the ground three or four inches in depth. The pieces were of the size of hailstones, grey in colour and pleasant to the taste. A white meal was prepared from them which provided a rather tasteless bread.

In January, 1846, at Jenischehir, in the west of Asia Minor, and the surrounding districts, during a time of famine, a similar fall took place. It lasted some days, and the pieces of lichen were of the size of hazel nuts. They were ground into flour, the bread from which was pronounced little inferior to wheat bread. Another account says that the manna was of a greyish-white colour, rather hard and irregular in form, inodorous and insipid.

In the year 1847 a report was made by General Jussuf, the Commander of the French troops, to the Governor of Algiers, on the subject of an edible lichen spread over a large portion of the Sahara and the Algerian plateaux, which he said had been a sustenance to the troops during the campaign, especially as provender for the horses. It was named Chlorangium jussufii, Link., but is identified by lichenologists as Lecanora esculenta, Pall.

On the whole there is no doubt that this curious natural product has been food for both men and animals in the several countries where it has fallen, but it is said that the sheep in Algiers do not thrive upon it, and no doubt it contains in its composition very slight nourishing properties. Sir Roderick Murchison, the geologist, wrote in the "Gardeners' Chronicle" for August 13th, 1864, as to specimens of manna-lichen——sent to him by the Austrian Internuncio at Constantinople——which fell with a gust of rain at Charput, north-west of Diarbekir, Asia Minor, that the specimens contained more than sixty-five per cent of oxalate of lime, with twenty-five per cent only of amylaceous matter, allied to starch, of which Iceland moss, the food of the reindeer, contains eighty per cent.

We may assume that the manna brought to the Israelites was, like the quails, a local natural product, provided in harmony with the preordained laws of the universe, and can proceed to consider whether the Lecanora esculenta, or some other product, most nearly accords with the Scriptural description of manna. Numerous trees and shrubs exude sweet gums, to some of which the name of manna is applied, but only a few of them are worthy consideration in connection with this subject.

One of these is yielded by a thorny leguminous shrub, very common from the North of India to Syria, and plentiful in the Wilderness of Sin. It is called by the Arabs "Alhaj" (Alhagi of Linnaeus). Two species, Alhagi maurorum and A. desertorum, are called by them "Ooshter Khar," or camel's-thorn, and in Mesopotamia "Agool." The leaves of A. maurorum exude a sweetish juice (Arabic "Ter enkjubin" moist honey), which concretes into small granular masses, and which is usually distinguished by the name of Persian manna. It contains, amongst various sorts of particles, a great number of globular, crystalline and almost transparent bodies of different sizes and of a yellowish-

white colour. The biggest of these does not exceed a large coriander seed in size, and they have somewhat the appearance of small lumps of mastic. Tournefort says that it is chiefly gathered about Tauris, a city of Persia, during great heats in that part of the world, but it is indigenous over a large part of the East, yielding manna, however, only in Persia, Bokhara, Arabia and Palestine. Extensive plains are in these countries covered with the camel's-thorn, and it is of great importance as food for camels as well as for sheep and goats. From the wounds produced by the browsing of these animals, the manna chiefly exudes. It is collected by the Arabs and caravans which cross the desert, and is used as food. It is gathered by shaking the branches. This Alhagi does not appear to be the same shrub as that which the traveller Wellsted found bearing manna in the Wady Hebron, on his journey from Tor to Mount Sinai, in September, 1836, "fifteen miles from the sea, and at an elevation of about 2,000 feet." That shrub was called "gavan," was about two feet high, and bore a striking resemblance to the broom.

In Kurdistan, Dr. Wright found in one part of the mountains great quantities of a sweet substance on the leaves of certain trees, generally the oak and gall-nut tree, and which is called "gezza" in Kurdish, and "manna" in Syriac. It forms on the leaves in such abundance that when they are dried and pounded it comes off in scales, and is collected and used as an article of food. When melted and strained in order to separate the crumbled leaves it is very delicious, and is eaten by the people often in preference to honey. In the summer it is collected in large quantities and put up for winter use.

Another kind of manna is also gathered in the Wilderness of Sin which appears to have more points of resemblance with the manna of the Israelites than either the edible lichen or the saccharine exudations above referred to. This substance exudes from the twigs of the tamarisk (Tamarix gallic a), figs. 2-4, a shrub or tree which is distributed over a large part of the northern hemisphere, especially near the shores of the Atlantic and Mediterranean seas and those of West Asia and North-West India, but which only yields manna in the valleys of the Sinaitic Peninsula, such as the Wady El Sheikh, the Wady Feiran, Wady Gharundel and the Wady Taibe, this local variety being known to botanists as T. gallic a (mannifera). In the Wady Feiran, the valley in which the Israelites are believed to have camped, and which leads from the Gulf of Suez towards Mount Sinai, the traveller passes through thick avenues of these trees, which are called by the natives "Turfeh" or "Tarffa" trees. They resemble a weeping-birch, and are especially rich in sap. The manna flows from the extremities of their slender pensile boughs in drops, described by Lepsius as sometimes as large as peas, sometimes no larger than pin-heads. The exudation was ascertained by Ehrenberg to be consequent upon the puncture of the Coccus manniparus, Ehr., a kind of scale insect or mealy-bug (fig. 6), which infests these trees in spring and summer, and which is allied to the cochineal insect (Coccus cacti), and the Coccus ilicis, of which the dye-stuff called "Kermes" is manufactured.

The gummy matter falls most plentifully in rainy seasons on the leaves and the ground beneath the trees (fig. 6), and when falling on clean rock is white as snow in colour. It soon hardens, but melts again (says the traveller Burckhardt) as soon as the sun shines upon it, so it is collected by the Arabs before sunrise, when it is coagulated. They clear away the leaves, dirt, etc., which adhere to it, boil it, strain it through a coarse cloth, and put it into leathern skins. In this way they preserve it till the following year, and use it, as they do honey, to pour on their unleavened bread and dip the bread into.

This substance corresponds in size, taste and colour, as also in the time and mode of its appearance and collection, with the manna of Exodus xvi, and Numbers xi. "We read" (says Carl Ritter, in his "Geography of Palestine") "that this food was provided after the Israelites had taken their journey from

Elim and had come into the Wilderness of Sin, which is between Elim and Sinai, on the fifteenth day of the second month after their departing out of the land of Egypt. This seems to correspond with the Wady Taibe, the most northern point, according to Seetzen, where the manna (Tamarix mannifera) is found, and the time after the passage of the Red Sea coincides accurately with the season when it is first observed in the Wady Feiran. "

It has been objected that very limited supplies of this manna are gathered in the present day, but travellers have recorded that the vegetation of the desert has been ruthlessly destroyed by the Bedouins, chiefly for the manufacture of charcoal, and we can be sure that in the time of the Israelites' wanderings the tamarisk extended in vast forests over the district where it is still found. The camel's-thorn was also no doubt much more abundant at that time than in the present day. Add to which, the yield of manna would be enormously increased if we suppose that the same winds which brought the quails in such profusion also brought an unusual quantity of the Coccus parasite, and that the trees were abnormally punctured.

It would be interesting to know the grounds upon which the learned author and editor of the "Natural History of Plants" have pronounced so decidedly in favour of the lichen, as it appears from the foregoing review of the subject that the food of the Israelites consisted, with a much greater degree of probability, of the exudation still known as manna, than of the dry and insipid lichen.

Some, however, may be inclined to think that the manna described with such exactness in the Scriptures was that of the tamarisk supplemented by the other sorts known to be common in the Sinaitic Peninsula.

GFL-008 [FALL OF MANNA]

Anonymous; Nature, 43:255, January 15, 1891.

The director of the central dispensary at Bagdad has sent to La Nature a specimen of an edible substance which fell during an abundant shower in the neighbourhood of Merdin and Diarbekir (Turkey in Asia) in August 1890. The rain which accompanied the substance fell over a surface of about ten kilometres in circumference. The inhabitants collected the "manna," and made it into bread, which is said to have been very good and to have been easily digested. The specimen sent to La Nature is composed of small spherules; yellowish on the outside, it is white within. Botanists who have examined it say that it belongs to the family of lichens known as Lecanora esculenta. According to Decaisne, this lichen, which has been found in Algeria, is most frequently met with on the most arid mountains of Tartary, where it lies among pebbles from which it can be distinguished only by experienced observers. It is also found in the desert of the Kirghizes. The traveller Parrot brought to Europe specimens of a quantity which had fallen in several districts of Persia at the beginning of 1828. He was assured that the ground was covered with the substance to the height of two decimetres, that animals ate it eagerly, and that it was collected by the people. In such cases it is supposed to have been caught up by a waterspout, and carried along by the wind.

Note that lichens grow slowly.

GFL-009 "PURPLE PATCHES"

Pedder, A.; Nature, 55:33, November 12, 1896.

I should be very glad if I could obtain information as to the cause and nature of certain "purple patches" which I have noticed from time to time for many years past, but have been unable to get explained. The patches in question occur during, or immediately after, rain, on the pavement or roadway; dashes of vivid purple, or rather violet, varying in size from small splashes or drops to patches as large as the palm of one's hand, but most commonly they are about the size of a shilling. When quite fresh, sometimes a little clot is observable in the centre of the splash. Sometimes I find one patch completely isolated, sometimes two or three in close proximity; sometimes, again, numerous little drops scattered over a certain space; once I counted twenty or thirty tiny dashes in about ten yards of pavement. When quite wet the violet colour can be rubbed up with a handkerchief or paper, which it stains as with "aniline purple" dye, as it does the pavement, and when once dry it is quite inerasible, and lasts till it is worn away by exposure, or the feet of passersby. I observe it to occur chiefly during warm rain after a dry or cold spell; never during dry weather, whether in summer or winter. During the past hot summer there was none to be found, but directly the weather changed in July, I saw it in various localities. This was also the case in the long cold winter of 1895, when on the breaking up of the frost there were plentiful patches to be seen up and down the streets; there was also a complete absence during the following summer, till the drought gave, and then again I found this appearance recur. I naturally observe it most in Bath, where I live; but it is not at all confined to one place or situation. I have found good specimens at such widely different places as the doorway of a hotel at Oban; the Castle Hill, Edinburgh; railway platform at Morecambe; doorstep at Windermere; in streets and roads at Cambridge, Bude, Penzance, St. Ives, Clevedon; once in a London street (Pall Mall East), and once some was found in a cold water bath.

I have from time to time made inquiries from various people who I thought would know, but have not been fortunate enough to meet any scientific person who has observed it. But one learned professor to whom I described the "patches," suggested whether "purple bacteria" would prove a solution to the mystery, and recommended me to inquire through the medium of your columns. I should be much obliged if some one would enlighten me, or mention some authority to whom I could refer.

GFL-010 "PURPLE PATCHES"

Southerden, F.; Nature, 58:521, September 29, 1898.

In Nature of November 12, 1896, there appeared a letter asking for some explanation of certain purple patches frequently noticed by the writer (A. Pedder) on roadways and pavements, especially at Bath. There were but three replies, two of which suggested "copying-ink" pencils as responsible.

The following notes, made recently in Derbyshire by myself, seem so nearly to fit the case that I venture to think a cause such as here described, or one closely allied, might explain some at any rate, of the cases mentioned. Here are the verbatim notes:-

GFL-011 LEAVES, HAY, POLLEN

"29/8/98——At Axe Edge last Wednesday I noticed on a coal-pit ventilating shaft (Thatch Marsh Colliery) on the moor certain deepish blue masses on a ledge near the base. Some masses brighter blue, others nearly black. Under a lens appeared to contain horny parts of larvae and many small seeds. They are probably the droppings of birds. They leave a bluish stain on the stone.

"To-day I noticed the same on some pieces of stone on the road to Govt's Bridge, a steep, rocky road.

"30/8/98.——Visited Axe Edge shaft again. There were no fresh deposits on it. This may be due to almost continuous rain the last four days; but the stains are still there. Also found deposit on one or two stones round shaft and on a piece of wooden staging. They were very plentiful, especially on the tops of the six posts of this staging, where one would expect birds to settle chiefly. The colour and stains were just the same—some reddish purple and some bluish purple. The colour is thus evidently due only to the excreta (?), and not to the body on which deposited. The seeds appear reddish, and it seems likely that the colour is due to them. (Bilberries are plentiful on the surrounding moor)."

"1/9/98.—The seeds are identical with bilberry, and on extracting the excreta with cold water a claret-red colour is obtained, which leaves a greenish-blue stain on paper."

Pedder, however, observed the patches in the middle of the winter as well as summer.

GFL-011 EXTRAORDINARY FLIGHT OF LEAVES

Shaw, James; Nature, 42:637, October 30, 1890.

The pastoral farm of Dalgonar is situated near the source of the Skarr Water, in the parish of Penpont, Dumfriessire. The ridge of hills on the farm as per Ordnance Survey is 1580 feet above sea-level. There are only five trees on the farm——two ash and three larch. An extraordinary occurrence presented itself to the eyes of Mr. Wright, my informant, at the end of October 1889, on this farm, which has been narrated to me in a letter received from him, as follows:-

"I was struck by a strange appearance in the atmosphere, which I at first mistook for a flock of birds, but as I saw them falling to the earth my curiosity was quickened. Fixing my eyes on one of the larger of them, and running about 100 yards up the hill until directly underneath, I awaited its arrival, when I found it to be an oak leaf. Looking upwards the air was thick with them, and as they descended in an almost vertical direction, oscillating, and glittering in the sunshine, the spectacle was as beautiful as rare. The wind was from the north, blowing a very gentle breeze, and there were occasional showers of rain.

"On examination of the hills after the leaves had fallen, it was found that they covered a tract of about a mile wide and two miles long. The leaves were wholly those of the oak. No oak trees grow in clumps together nearer than eight miles. The aged shepherd, who has been on the farm since 1826, never witnessed a similar occurrence. "

Why only oak leaves ?

GFL-012 A SHOWER OF HAY

Anonymous; Scientific American, 33:197, September 25, 1875.

Dr. Hawtrey Benson, of Dublin, writing in the Dublin Daily Express under date July 27, describes a remarkable shower of small pieces of hay which he witnessed at Monkstown that morning. It appeared in the form of "a number of dark flocculent bodies floating slowly down through the air from a great height, appearing as if falling from a very heavy dark cloud, which hung over the house." The pieces of hay picked up were wet, "as if a very heavy dew had been deposited on it. The average weight of the larger flocks was probably not more than one or two ounces, and, from that, all sizes were perceptible down to a simple blade. The air was very calm, with a gentle under current from S. E.; the clouds were moving in an upper current from S. S. W." The air was tolerably warm and dry, and the phenomenon is thus accounted for by Dr. J. W. Moore: "The coincidence of a hot sun and two air currents probably caused the development of a whirlwind some distance to the south of Monkstown. By it the hay was raised into the air, to fall, as already described, over Monkstown and the adjoining districts."

A similar shower of hay fell near Wrexham, England, July 25.

GFL-013 JULY 29, 1875. SHOWER OF HAY NEAR DUBLIN

Anonymous; Nature, 126:153, July 26, 1930.

About 9:30 a.m. a quantity of hay fell from the sky at Monkstown near Dublin, over an area of more than a mile in diameter, the shower lasting five minutes. There was a dark cloud overhead and the hay was wet, but no rain was falling, and the air was very calm.

Whirlwinds frequently suck hay high up into the air, so that the "whirlwind theory" is more reasonable here. See a fuller account in [GFL-012],

GFL-014 [SHOWER OF GRAIN]

Anonymous; American Journal of Science, 1:41:40, 1841.

Col. Sykes communicated the contents of a letter from India, from Capt. Aston, on the subject of a recent singular shower of grain. He stated that 60 or 70 years ago, a fall of fish had occurred during a storm in the Madras Presidency. This fact is recorded by Major Harriott, in his "Struggles through Life," as having taken place while the troops were on the line of march, and some of the fish falling upon the hats of the European troops, they were collected and made into a curry for the general. This fact was probably for fifty years regarded as a traveller's tale, but within the last ten years, so many other instances have been witnessed, and publicly attested, that the story is no longer doubted. The shower of grain above mentioned, took place March 24, 1840, at Rajket in Kattywar, during one of those thunder storms to which that month is subject, and it was found that the grain had not only fallen upon the

town, but also upon a considerable extent bf country round the town. Capt. A. collected a quantity of the seed, and transmitted it to Col. Sykes. The natives flocked to Capt. A. to ask for his opinion of this phenomenon: for not only did the raining of grain upon them from heaven, excite terror, but the omen was aggravated by the fact that the seed was not one of the cultivated grains of the country, but was entirely unknown to them. The genus and species was not immediately recognized by some botanists to whom it was shown, but it was thought to be either a Spar'ium, or a Vicia. A similar force to that which elevates fish into the air, no doubt operated on this occasion, and this new fact corroborates the phenomena, the effects of which had been previously witnessed.

GFL-015 A MARVELLOUS "RAINFALL" OF SEEDS

Wallace, R. Hedger; Notes and Queries, 8:12:228, September 18, 1897.

The following is a cutting from a publication entitled the Golden Penny, and gives some details regarding the "extraordinary phenomenon" of a rainfall of seeds :-

"Some days ago the province of Macerata, in Italy, was the scene of an extraordinary phenomenon. Half an hour before sunset an immense number of small blood-coloured clouds covered the sky. About an hour later a cyclone storm burst, and immediately the air became filled with myriads of small seeds. The seeds fell over town and country, covering the ground to a depth of about half an inch. The next day the whole of the scientists of Macerata were abroad in order to find some explanation. Prof. Cardinali, a celebrated Italian naturalist, stated that the seeds were of the genus Cercis, commonly called Judas Tree, and that they belonged to an order of Leguminosae found only in Central Africa or the Antilles. It was found, upon examination, that a great number of the seeds were actually in the first stage of germination. "

Are there many authentic instances of a rainfall of seeds; and are there any in the British Isles ?

The transport of seeds by wind is certainly reasonable. The "strange" part is segregation of material——where is the other loose material that must exist in the area where the seeds were picked up? If some of the seeds were germinating, they were likely on or in the ground.

GFL-016 ON A METEORITE WHICH FELL NEAR JAFFERABAD IN INDIA ON APRIL 28, 1893

Judd, John W. ; Nature, 49:32-33, November 9, 1893.

Particulars have recently reached this country concerning a fall of a meteorite near Jafferabad in the south-east of Kathiawar, a native State adjoining the Bombay presidency. Dr. J. W. Evans, the geologist to the State of Kathiawar, has kindly forwarded to me a translation of the report sent in by the local official. It is curious that a fall of Nagali Jaowar (a kind of

seed used as food by the poorer people of the country) is said to have occurred at the same time as the fall of the stone. As suggested by Dr. Evans, the seed may have been carried a short distance by the wind, which is very strong on the coast of Kathiawar at the time of year when the fall occurred. The spot where the fall took place is a flat region of recent limestone. Dr. Evans adds that the official report is interesting, as it is the account of a man who never heard of a meteorite, and to whom the fall of grain is as probable as that of stones.

The report that follows describes a typical meteorite fall and says nothing about seeds.

GFL-017 A SHOWER OF MEAT

Anonymous; Scientific American, 34:197, March 25, 1876.

The Bath County (Ky.) News says: On Friday, March 3, 1876, a shower of meat fell near the house of Allen Crouch, who lives some two or three miles from the Olympian Springs in the southern portion of the county, covering a strip of ground about one hundred yards in length and fifty wide. Mrs. Crouch was out in the yard at the time, engaged in making soap, when meat which looked like beef began to fall around her. The sky was perfectly clear at the time, and she said it fell like large snow flakes, the pieces as a general thing not being much larger. One piece fell near her which was three or four inches square. Mr. Harrison Gill, whose veracity is unquestionable, and from whom we obtain the above facts, hearing of the occurrence, visited the locality the next day, and says he saw particles of meat sticking to the fences and scattered over the ground. The meat when it fell appeared to be perfectly fresh.

The correspondent of the Louisville Commercial, writing from Mount Sterling, corroborates the above, and says the pieces of flesh were of various sizes and shapes, some of them being two inches square. Two gentlemen, who tasted the meat, expressed the opinion that it was either mutton or venison.

GFL-018 THE KENTUCKY MEAT SHOWER

Edwards, A. Mead; Scientific American Supplement, 2:473, July 22, 1876.

In your Supplement of July 1st is an article, taken from the Sanitarian, on the Kentucky meat-shower, and introducing the article, you express an opinion that we have therein a solution of the question as to what the substance constituting the meat-shower was, in Mr. Brandeis' assertion that it consisted of masses of nostoc, a low form of vegetable existence. As the public seems to

be still interested in the matter, and as, apparently, they have not yet learned what it really is, permit me say a few words thereon. We have in the city of Newark, N. J., an active, wide-awake organization known as the Newark Scientific Association, at the meetings of which novel scientific matters are discussed and sifted. At one of our meetings, for the first time, the true solution of Mr. Edison's so-called "etheric force" took place; and at our meeting in March last the Kentucky meat-shower was discussed, and at that time I made a communication reviewing what was known with regard to so-called showers of meat, blood, and colored matters generally. At that time, and before I had seen any specimens from Kentucky, I expressed an opinion that it would turn out to be nostoc. When, then, I saw Mr. Brandeis' communication, I felt convinced that he had solved the problem, and knowing him well, I called on him to see if he could give me a specimen of the original article. He kindly placed his whole supply in my hands, and informed me that it had been received from Prof. Chandler, who gave it to a physician in Brooklyn, who in turn gave it to him, Mr. B. Soon after, Dr. Allan McLane Hamilton published a letter in the New York Medical Record, wherein he said that he had received a piece of the Kentucky shower from Prof. Chandler, and a microscopic examination of it by himself and Dr. J. W. S. Arnold revealed the fact that it consisted of lung tissue either from a human infant or a horse, the structure of the organ in these two cases being very similar. At once I called on Dr. Hamilton, and he likewise placed his specimens in my hands, at the same time informing me that two morsels of the shower had been sent from Kentucky to the editor of the Agriculturist; that gentleman placed them in the hands of Prof. Chandler. One went to Dr. Hamilton, the other to Brooklyn, and eventually into the hands of Mr. Brandeis. So I evidently had the whole matter in my possession. On examination I found Dr. Hamilton's specimen to be, as he stated, lung tissue, in one portion of which cartilage was to be seen beautifully exhibited. Mr. Brandeis' specimen, when examined by means of the microscope, turned out to be lung tissue also, but not in as good a state of preservation as the first mentioned. Soon thereafter fwas shown by Prof. J. Phin, of the American Journal of Microscopy, a prepared specimen sent from Kentucky to Mr, Walmsley, of Philadelphia, which was undoubtedly striated muscular fibre. And subsequent thereto he showed me another specimen sent to him by Mr. A. T. Parker, of Lexington, Ky., which was also striated muscular fibre. Being determined to follow the matter up, I wrote to Mr. Parker, and he very kindly sent me three specimens, two in the natural state as they fell, and one prepared and mounted for the microscope. The last-named consists entirely of cartilage; one of the others is likewise a mass of cartilage, while the remaining portion shows a few striated muscular fibres, along with what appears to be dense connective tissue, but in such a condition that its exact character can not be well made out. I am promised further specimens and information by Mr. Parker, who has been unsparing in his endeavors to elucidate the mystery, whilst he has been at the same time extremely liberal in the matter of distributing specimens. So much for the facts. Every specimen I have examined has proved to be of animal origin, showing that the Kentucky shower was a veritable "meat" shower. As to whence it came I have no theory. Mr. Parker informs me that the favorite theory in the locality is, that it proceeded from a flock of buzzards who, as is their custom, seeing one of their companions disgorge himself, immediately followed suit. In fact, such an occurrence has been actually seen to occur, so that it would seem that the whole matter is capable of a reasonable and simple explanation, and we may expect to hear of similar downfalls in other localities.

GFT-001 THUNDERBOLTS

Anonymous; Cornhill Magazine, ns 50:513-528, 1884.

This is a long and condescending article, written as if science knew everything. The "noble savage, " in particular, comes in for some hard knocks; and, it seems to be the writer's intent to assert that all who did not subscribe to the science of 1884 were also savages. It is interesting that the discovery of radioactivity was only 12 years away. The contemporary article by Carus-Wilson (vol. G3) is more open-minded, though not necessarily more correct!

The subject of thunderbolts is a very fascinating one, and all the more so because there are no such things in existence at all as thunderbolts of any sort. Like the snakes of Iceland, their whole history might, from the positive point of view at least, be summed up in the simple statement of their utter non-entity. But does that do away in the least, I should like to know, with their intrinsic interest and importance? Not a bit of it. It only adds to the mystery and charm of the whole subject. Does any one feel as keenly interested in any real living cobra or anaconda as in the non-existent great sea-serpent? Are ghosts and vampires less attractive objects of popular study than cats and donkeys? Can the present King of Abyssinia, interviewed by our own correspondent, equal the romantic charm of Prester John, or the butcher in the next street rival the personality of Sir Roger Charles Doughty Tichborne, Baronet? No, the real fact is this: if there were thunderbolts, the question of their nature and action would be a wholly dull, scientific, and priggish one; it is their unreality alone that invests them with all the mysterious weirdness of pure fiction.

But if seeing is believing, it is equally true, as all who have looked into the phenomena of spiritualism and 'psychical research' (modern English for ghost-hunting) know too well, that believing is seeing also. The origin of the faith in thunderbolts must be looked for (like the origin of the faith in ghosts and 'psychical phenomena') far back in the history of our race. The noble savage, at that early period when wild in woods he ran, naturally noticed the existence of thunder and lightning, because thunder and lightning are things that forcibly obtrude themselves upon the attention of the observer, however little he may by nature be scientifically inclined. Indeed, the noble savage, sleeping naked on the bare ground, in tropical countries where thunder occurs almost every night on an average, was sure to be pretty often awaked from his peaceful slumbers by the torrents of rain that habitually accompany thunderstorms in the happy realms of everlasting dog-days. Primitive man was thereupon compelled to do a little philosophising on his own account as to the cause and origin of the rumbling and flashing which he saw so constantly around him. Naturally enough, he concluded that the sound must be the voice of somebody; and that the fiery shaft, whose effects he sometimes noted upon trees, animals, and his fellow-man, must be the somebody's arrow.

Now, this idea about the arrows is itself very significant of the mental attitude of primitive man, and of the way that mental attitude has coloured all subsequent thinking and superstition upon this very subject. Curiously enough, to the present day the conception of the thunderbolt is essentially one of a bolt-— that is to say, an arrow, or at least an arrowhead. All existing thunderbolts (and there are plenty of them lying about casually in country houses and local museums) are more or less arrow-like in shape and appearance; some of them,

indeed, as we shall see by-and-by, are the actual stone arrowheads of primitive man himself in person. Of course the noble savage was himself in the constant habit of shooting at animals and enemies with a bow and arrow. When, then, he tried to fi'gure to himself the angry god, seated in the storm-clouds, who spoke with such a loud rumbling voice, and killed those who displeased him with his fiery darts, he naturally thought of him as using in his cloudy home the familiar bow and arrow of this nether planet. To us nowadays, if we were to begin forming the idea for ourselves all over again de novo, it would be far more natural to think of the thunder as the noise of a big gun, of the lightning as the flash of the powder, and of the supposed 'bolt' as a shell or bullet. There is really a ridiculous resemblance between a thunderstorm and a discharge of artillery. But the old conception derived from so many generations of primitive men has held its own against such mere modern devices as gunpowder and rifle balls; and none of the objects commonly shown as thunderbolts are ever round: they are distinguished, whatever their origin, by the common peculiarity that they more or less closely resemble a dart or arrowhead.

Let us begin, then, by clearly disembarrassing our minds of any lingering belief in the existence of thunderbolts. There are absolutely no such things known to science. The two real phenomena that underlie the fable are simply thunder and lightning. A thunderstorm is merely a series of electrical discharges between one cloud and another, or between clouds and the earth; and these discharges manifest themselves to our senses under two forms—to the eye as lightning, to the ear as thunder. All that passes in each case is a huge spark——a commotion, not a material object. It is in principle just like the spark from an electrical machine; but while the most powerful machine of human construction will only send a spark for three feet, the enormous electrical apparatus provided for us by nature will send one for four, five, or even ten miles.

Primitive man naturally took to the grosser and more material conception. He figured to himself the thunderbolt as a barbed arrowhead; and the forked zigzag character of the visible flash, as it darts rapidly from point to point, seemed almost inevitably to suggest to him the barbs, as one sees them represented on all the Greek and Roman gems, in the red right hand of the angry Jupiter.

The thunderbolt being thus an accepted fact, it followed naturally that whenever any dart-like object of unknown origin was dug up out of the ground, it was at once set down as being a thunderbolt; and, on the other hand, the frequent occurrence of such dart-like objects, precisely where one might expect to find them in accordance with the theory, necessarily strengthened the belief itself. So commonly are thunderbolts picked up to the present day that to disbelieve in them seems to many country people a piece of ridiculous and stubborn scepticism. Why, they've ploughed up dozens of them themselves in their time, and just about the very place where the thunderbolt struck the old elm tree two years ago, too.

The most favourite form of thunderbolt is the polished stone hatchet or 'celt' of the newer stone age men. I have never heard the very rude chipped and unpolished axes of the older drift men or cave men described as thunderbolts: they are too rough and shapeless ever to attract attention from any except professed archaeologists. Indeed, the wicked have been known to scoff at them freely as mere accidental lumps of broken flint, and to deride the notion of their being due in any way to deliberate human handicraft. These are the sort of people who would regard a grand piano as a fortuitous concourse of atoms. But the shapely stone hatchet of the later neolithic farmer and herdsman is usually a beautifully polished wedge-shaped piece of solid greenstone; and its

edge has been ground to such a delicate smoothness that it seems rather like a bit of nature's exquisite workmanship than a simple relic of prehistoric man. There is something very fascinating about the naif belief that the neolithic axe is a genuine unadulterated thunderbolt. You dig it up in the ground exactly where you would expect a thunderbolt (if there were such things) to be. It is heavy, smooth, well shaped, and neatly pointed at one end. If it could really descent in a red-hot state from the depths of the sky, launched forth like a cannon-ball by some fierce discharge of heavenly artillery, it would certainly prove a very formidable weapon indeed; and one could easily imagine it scoring the bark of some aged oak, or tearing off the tiles from a projecting turret, exactly as the lightning is so well known to do in this prosaic workaday world of ours. In short, there is really nothing on earth against the theory of the stone axe being a true thunderbolt, except the fact that it unfortunately happens to be a neolithic hatchet.

All the world over, this simple and easy belief, that the buried stone axe is a thunderbolt, exists among Europeans and savages alike. In the West of England, the labourers will tell you that the thunder-axes they dig up fell from the sky. In Brittany, says Mr. Tylor, the old man who mends umbrellas at Carnac, beside the mysterious stone avenues of that great French Stonehenge, inquires on his rounds for pierres de tonnerre, which of course are found with suspicious frequency in the immediate neighbourhood of prehistoric remains. In the Chinese Encyclopaedia we are told that the 'lightning stones' have sometimes the shape of a hatchet, sometimes that of a knife, and sometimes that of a mallet. And then, by a curious misapprehension, the sapient author of that work goes on to observe that these lightning stones are used by the wandering Mongols instead of copper and steel. It never seems to have struck his celestial intelligence that the Mongols made the lightning stones instead of digging them up out of the earth. So deeply had the idea of the thunderbolt buried itself in the recesses of his soul, that though a neighbouring people were still actually manufacturing stone axes almost under his very eyes, he reversed mentally the entire process, and supposed they dug up the thunderbolts which he saw them using, and employed them as common hatchets. This is one of the finest instances on record of the popular figure which grammarians call the hysteron proteron, and ordinary folk describe as putting the cart before the horse. Just so, while in some parts of Brazil the Indians are still laboriously polishing their stone hatchets, in other parts the planters are digging up the precisely similar stone hatchets of earlier generations, and religiously preserving them in their houses as undoubted thunderbolts. I have myself had pressed upon my attention as genuine lightning stones, in the West Indies, the exquisitely polished greenstone tomahawks of the old Carib marauders. But then, in this matter, I am pretty much in the position of that philosophic sceptic who, when he was asked by a lady whether he believed in ghosts, answered wisely, 'No, madam, I have seen by far too many of them.'

One of the finest accounts ever given of the nature of thunderbolts is that mentioned by Adrianus Tollius in his edition of 'Boethius on Gems.' He gives illustrations of some neolithic axes and hammers, and then proceeds to state that in the opinion of philosophers they.are generated in the sky by a fulgureous exhalation (whatever that may look like) conglobed in a cloud by a circumfixed humour, and baked hard, as it were, by intense heat. The weapon, it seems, then becomes pointed by the damp mixed with it flying from the dry part, and leaving the other end denser; while the exhalations press it so hard that it breaks out through the cloud, and makes thunder and lightning.

GFT-001 THUNDERSTONES

Another and very different form of thunderbolt is the belemnite, a common English fossil often preserved in houses in the west country with the same superstitious reverence as the neolithic hatchets. The very form of the belemnite at once suggests the notion of a dart or lance-head, which has gained for it its scientific name. At the present day, when all our girls go to Girton and enter for the classical tripos, I need hardly translate the word belemnite 'for the benefit of the ladies,' as people used to do in the dark and unemancipated eighteenth century; but as our boys have left off learning Greek just as their sisters are beginning to act the 'Antigone'at private theatricals, I may perhaps be pardoned if I explain, 'for the benefit of the gentlemen,' that the word is practically equivalent to javelin-fossil. The belemnites are the internal shells of a sort of cuttle-fish which swam about in enormous numbers in the seas whose sediment forms our modern lias, oolite, and gault. A great many different species are known and have acquired charming names in very doubtful Attic at the hands of profoundly learned geological investigators, but almost all are equally good representatives of the mythical thunderbolt. The finest specimens are long, thick, cylindrical, and gradually tapering, with a hole at one end as if on purpose to receive the shaft. Sometimes they have petrified into iron pyrites or copper compounds, shining like gold, and then they make very noble thunderbolts indeed, heavy as lead, and capable of doing profound mischief if properly directed. At other times they have crystallised in transparent spar, and then they form very beautiful objects, as smooth and polished as the best lapidary could possibly make them. Belemnites are generally found in immense numbers together, especially in the marlstone quarries of the Midlands, and in the lias cliffs of Dorsetshire. Yet the quarrymen who find them never seem to have their faith shaken in the least by the enormous quantities of thunderbolts that would appear to have struck a single spot with such extraordinary frequency. This little fact also tells rather hardly against the theory that the lightning never falls twice upon the same place.

As if on purpose to confuse our already very vague ideas about thunderbolts, there is one special kind of lightning which really seems intentionally to stimulate a meteorite, and that is the kind known as fireballs or (more scientifically) globular lightning. A fireball generally appears as a sphere of light, sometimes only as big as a Dutch cheese, sometimes as large as three feet in diameter. It moves along very slowly and demurely through the air, remaining visible for a whole minute or two together;•and in the end it generally bursts up with great violence, as if it were a London railway station being experimented upon by Irish patriots. At Milan one day a fireball of this description walked down one of the streets so slowly that a small crowd walked after it admiringly, to see where it was going. It made straight for a church steeple, after the common but sacrilegious fashion of all lightning, struck the gilded cross on the topmost pinnacle, and then immediately vanished, like a Virgilian apparition, into thin air.

A few years ago, too, Dr. Tripe was watching a very severe thunderstorm, when he saw a fire-ball come quietly gliding up to him, apparently rising from the earth rather than falling towards it. Instead of running away, like a practical man, the intrepid doctor held his ground quietly and observed the fiery monster with scientific nonchalance. After continuing its course for some time in a peaceful and regular fashion, however, without attempting to assault him, it finally darted off at a tangent in another direction, and turned apparently into forked lightning. A fireball, noticed among the Glendowan Mountains in Donegal, behaved even more eccentrically, as might be expected from its Irish antece-

dents. It first skirted the earth in a leisurely way for several hundred yards like a cannon-ball; then it struck the ground, ricocnetted, and once more bounded along for another short spell; after which it disappeared in the boggy soil, as if it were completely finished and done for. But in another moment it rose again, nothing daunted, with Celtic irrepresslbility, several yards away, pursued its ghostly course across a running stream (which shows, at least, there could have been no witchcraft in it), and finally ran to earth for good in the opposite bank, leaving a round hole in the sloping peat at the spot where it buried itself. Where it first struck, it cut up the peat as if with a knife, and made a broad deep trench which remained afterwards as a witness of its eccentric conduct. If the person who observed it had been of a superstitious turn of mind, we should have had here one of the finest and most terrifying ghost stories on the entire record, which would have made an exceptionally splendid show in the Transactions of the Society for Psychical Research. Unfortunately, however, he was only a man of science, ungifted with the precious dower of poetical imagination; so he stupidly called it a remarkable fireball, measured the ground carefully like a common engineer, and sent an account of the phenomenon to that far more prosaic periodical, the 'Quarterly Journal of the Meteorological Society.' Another splendid apparition thrown away recklessly, forever!

GFT-002 OBSERVED FALL OF AN AEROLITE NEAR ST. ALBANS

Bullen, G. E. ; Nature, 89:34, March 14, 1912, and 89:62, March 21, 1912.

During a heavy thunderstorm which ensued on Monday, March 4, between 2.30 p. m. and 4.15 p. m., an aerolite was observed to fall at Colney Heath, near St. Albans. The observer, who has placed the specimen in my hands for examination, stated that the stone fell within a few feet from where he was standing, and that it entered the ground for a distance of about 3 ft. Its fall was accompanied by an unusually heavy clap of thunder. The example weighs 5 lb. 14-1/2 oz., and measures 6-3/4 in. x 5-5/8 in. at its greatest length and breadth respectively. The mass is irregularly ovate on the one side, and broken in outline on the other. The actual surface throughout is fairly deeply pitted, and under magnification exhibits the usual chondritic structure of the crystalline matter with interspersed particles of what appears to be nickeliferous iron.

In the following issue comes evidence that the "aerolite" was not meteoric in nature. If not meteoric, what was it? A thunder stone ?

Under the above heading in the issue of Nature for last week I reported upon the circumstances and other details of a supposed fall of a meteorite during the storm of March 4, as described to me by an observer, Mr. H. L. G. Andrews, at Colney Heath, near St. Albans. I have now submitted the stone for examination to Dr. George T. Prior, of the British Museum (Natural History), who informs me that it is not of meteoric origin.

GFT-003 THUNDERSTONES

GFT-003 [METEORITE FALLS DURING THUNDERSTORM]

Anonymous; Nature, 81:134, July 29, 1909.

Mr. H. Garrett, writing from Greensted Rectory by Ongar to the Times (July 28), says:- "During the severe thunderstorm on the 13th inst. a meteoric stone fell in the stable yard here with a terrific explosion when within a few feet of the ground, embedding itself in the gravel about 8 inches, the ground around for several feet being perforated with small holes caused by the fragments. The main part and fragments which we could collect weighed 1 lb. 13 oz. The fall was witnessed by my daughters, who were sheltering about eight yards away."

GFT-004 CATALOGUE OF METEORITES AND FIREBALLS

Anonymous; Report of the British Association, 90-91, 1860.

September 1850, Barcelona, Spain. At the beginning of the month; Dr. Joaquin Balcells of Barcelona, relates the fall of a thunderstone (?). Sp. gr. 8.12; dark colored, very hard; conical form; made a hole in the ground. Said to contain no arsenic; some silica and alumina and sulfurous iron. Certainly rather doubtful; and perhaps a nodule of pyrites.

GFT-005 [THUNDERSTORM AND METEOR?]

Anonymous; Nature, 43:590, April 23, 1891.

The following cutting from the Sydney Morning Herald—date not stated—has been sent to us for publication:-'The barque Killarney had both a stormy and an extraordinary passage, in one portion of which she stood a good chance of being placed on the list of missing vessels. At 9 p. m. on October 15, 1890, when the barque was 50 miles east of Kent's Group, there was a sudden shift of wind during a heavy thunderstorm. In the midst of a heavy clap a bulky mass was heard to fall into the sea about 200 yards from the vessel. The roar of it coming through the air was quite distinct from that of the thunder, and spray was thrown fully 40 feet high on its reaching the water. The falling mass is believed to have been a meteor. "

Tales such as this perpetuate the thunderbolt belief.

SECTION GL: LUMINOUS PHENOMENA

Unusual Rights in the sky are rather common. Such lights were the primary basis of the UFO rage of the 1950s and 1960s. Although most strange lights are simple reflections or misinterpretations of common events, there are still many luminous phenomena that are not readily explained in conventional terms. It is in this section that these strange lights, glows, flashes, and other luminous structures are gathered.

GLA Aurora-like phenomena. Glows, bands, and shafts of light seen in the sky, sometimes very close to the earth's surface, but with characteristics not found in the usual aurora.

GLB Ball lightning.

GLD Electric discharge. Glows, flames, sparks, and spheres of light that apparently, but not necessarily, originate in electrical discharges. Included are mountain-top glows, St. Elmo's fire, earthquake lights, and tornado lights.

GLL Lightning. Unusual forms of lightning (excluding ball lightning, which is in GLB). Silent lightning, lightning without clouds, and the "pranks" of lightning.

GLM Meteor-like phenomena. Slow fireballs; fireballs that change course or follow anomalous trajectories. Supposed meteors that cause unexpected geophysical effects, such as strange sounds, odors, and precipitation.

GLN Nocturnal lights. Maneuvering lights, often appearing in the same location year after year. Included are "spooklights" and will-o'-wisps (ignis fatuus).

GLW Light wheels. The luminous, wheel-like structures seen most often in the Indian Ocean. Also, the apparently associated white, milky, and/or phosphorescent seas.

LUMINOUS PHENOMENA

GLA-024 AURORAL PHENOMENA

Ingleby, C. M, ; Nature, 23:363, February 17, 1881.

It is perhaps worth a note that my daughter saw at Folkestone a very unusual phenomenon on the evening of January 25, a little before 6.30. Some distance to the left of Orion (for the night was clear and starry) she observed a small cloud of a bright golden hue, from which streamers of great brilliancy darted in various directions, the cloud alternately paling and brightening. She describes the streamers as like small meteors, leaving trails of light behind them.

The flashing of this cloud could be due to electrical discharges.

GLA-025 ATMOSPHERIC PHENOMENON

B. ; Nature, 22:607, October 28, 1880.

Last evening (October 21) at 5:45 p.m. I observed four huge radiating arms of faint white light, like the spokes of a gigantic wheel, rising from a centre apparently on the west-south-west horizon, and extending almost to the zenith. I say apparently on the west-south-west horizon, because an intervening house prevented me from seeing the nucleus of the diverging rays. The aspect of the phenomenon was more suggestive of an aurora than anything else I know of, but the beams of light seemed to be quite stationary, and although I fancied their brilliancy increased at one time for a few moments, I cannot be sure. Other fainter rays appeared to me to divide the west-south-west sky with those I have mentioned; but on that point I am also not sure. The sun set at 4:53 p. m., and twilight ended about 6:43 p.m., at which time the appearance I have attempted to describe was no longer visible. The sky was heavily clouded.

Superficially this observation seems closely associated with the sun; in other words, it is likely a refraction phenomenon.

GLA-026 UNUSUAL SKY APPEARANCE

Abbot, C. G. ; Science, 81:294, March 22, 1935.

A correspondent from Vienna, Va., writes that on either January 22 or 23, about 8 o' clock in the evening, she saw a light flashing in the southwest something like lightning. It would flare up several times, then die down. As she watched it, it became very vivid till it seemed to come from a great blazing light, almost a ball of fire. All this time it was moving around the horizon from the southwest until it had almost reached the starting point. She thought it perhaps more vivid when in the north, and that it seemed to be dying away in the southeast. It appeared to be very low, just showing above the foothills.

I myself was driving along Wisconsin Avenue in Washington on the evening in question, with my wife, and we were startled by what was probably the same appearance. It resembled what is called "heat lightning, " only that it seemed to

be very near indeed and not associated with any noise. The night; as I recall it, was very cold and dry, and I believe on the turn between two contrasting types of weather.

GLA-027 THE AURORA

Anonymous; Knowledge, 2:419-420, November 24, 1882.

After describing a "magnificent aurora" in conventional terms, the following description of an unusual aspect is presented. Numerous accounts of this event from Nature are quoted in volume Gl and the next entry.

At about five minutes past six a singular phenomenon was observed. A cloud of whitish light, shaped like torpedo, passed from the south-eastern to the north-western horizon (some accounts say from east to west, but the true direction was from a little east of south-east to a little north of north-west). It was of nearly uniform brightness. Its length was nearly ninety degrees. (One observer says that its size, compared with that of the moon (which was shining brightly at the time), was as a herring compared with a sixpenny-piece; but as he does not name the price of his illustrative herring, the illustration is not so satisfactory as could be wished: does he mean a penny herring, or one of those which may be obtained, we understand, at two a penny?) It passed across the heavens in about two minutes. It is described as a cometary body; but as it moved almost exactly at right-angles to the magnetic meridian, there can be very little doubt it was an electrical phenomenon. The appearance is akin to that sometimes seen in high latitudes, as the auroral streamers vary in position, aggregation, and length, seeming to throw folds of brightness, shaped like the folds of a curtain, athwart the auroral arch.

GLA-028 THE TRUE ORBIT OF THE AURORAL METEOROID OF NOVEMBER 17, 1882.

Groneman, H. J. H.; Nature, 28:105-107, May 31, 1883.

Several descriptions of this phenomenon are presented in Volume Gl. (GLA-007, GLA-011, GLA-012, GLA-014, and GLA-015)

After many fruitless efforts to conciliate the apparently widely diverging data, given by the numerous observations of this most interesting phenomenon; and after having been many times on the same point as Mr. H. D. Taylor (vol. xxvii, p. 434), who has given the first approximate calculations of this orbit, namely, "to give up the reconciling of such contradictory evidence, " I have devoted my Easter holidays to new research on the true orbit.

The details of Groneman's analysis are omitted. In essence he attempted to find an orbit that was reasonably consistent with the observations.

I hope that the observers will be content with the degree of harmony between their observations and my results. I believe that a small change in the direction of the orbit's plane will give still more harmony between calculation and observation, but the orbit found satisfies the chief observed facts, and gives the greatest divergence, where the observations have the smallest sharpness. I believe I have proved by this research that there existed, with the aurora of November 17, 1882, cosmic dust, passing through the upper strata of our atmosphere with great velocity, and giving, according to the most interesting observation of Mr. Rand Capron (p. 84), "the usual green line" of the aurora spectrum. Thus nature itself has been so kind as to give an experiment that till now, and perhaps for ever, is beyond human power, for our means are not sufficient to throw projectiles with several thousand metres velocity; and it is very remarkable that this experiment comes at the same time as the interesting experiment of Prof. Lemstrom, showing that electric currents are able to give a development of light in our atmosphere, possessing the same number of undulations in a second as the auroral light. Now our meteoroid being a part of an aurora, it gives a stronger proof of the origin of that phenomenon than Prof. Lemstrom's experiment, the greatest attraction of which is that we are able to repeat it arbitrarily and with our own means. Further, I have always maintained that electricity, excited easily by friction, must be one of the causes of the auroral light ("Theorie Cosmique de l'Aurore Polaire, " Journal des Spectroscopistes Italiens, 1878, vol. vii. chap, ii.), and it seems to me very plausible that cosmic matter, approaching the earth, induces electric currents through the air. Therefore I think that the results of Prof. Lemstrom are in full harmony with the idea of a cosmic origin of aurorae.

The orbit found does not reach the surface of the earth, being at its nearest approach still 123. 9 kilometres {1 mile equals 1609. 3 metres; 1 German geogr. mile equals 7420.4 metres) or 16.7 geogr. miles from that surface. The length of the orbit from the Utrecht perpendicular line to the Utrecht horizon is 1, 483, 070 metres, and this line being run over in 60 seconds, the mean relative velocity was 24,673 metres, 15.3 miles, or more than 3 German geogr. miles.

The dimensions of the "cosmic cloud" (length 40°, width 5°, as seen from Ipswich) are: length equals 182,594, width equals 21,921 metres. By these dimensions, probably too great from irradiation, it must show at Utrecht an apparent length of 50°; but theextremities were tapered and therefore the length strongly influenced by the transparency of the air. It is therefore not strange that the apparent length at Utrecht was during some few seconds 90 degrees.

To conclude, I will remark that the proved existence of a cosmic cloud, preserving its pretty sharp sides during so long a path as that from Sweden to the Atlantic Ocean, notwithstanding its velocity of 247 kilometres, proves its particles to be nearly spherical. Otherwise these particles should necessarily have diverged sideways from the orbit and spread into space. In connection with the fact observed by Mr. P. Zeeman (p. 297), that auroral clouds gave interference-phenomena, when coming before the moon's disk, and these latter phenomena requiring (Dagnin, "Traite de Phys., " iv. p. 446) the presence of nearly equal particles of dusty matter, Mr. Zeeman's observation proves the same property in the particles of the auroral cloud. Being nearly equal, but not perfectly, the tangential atmospheric resistance must throw the smallest particles backward, and this explains the oblong shape of the cloud.

GLA-029 AURORA-LIKE PHENOMENA

GLA-029 OBSERVATIONS OF AN AURORAL BEAM, APRIL 22,1852

Herrick, E. C; Report of the British Association, part 2, 130-131, 1832.

During the evening of Thursday, April 22, 1852, there was seen at this place (New Haven, Conn.,) a display of the aurora borealis, not very extensive, but yet of much interest, because it presented one phase of the phenomenon well suited for satisfactory observations of parallax.

At about half past seven o'clock there was in the north a shooting of streamers up to an altitude of 20° or 30°, through an amplitude of about 100°. The display soon subsided into a general bright light. On going to the door about twenty minutes after nine, I saw in the northwest a segment of an auroral arc, belt, or beam, entirely isolated, moderately brilliant, having well-defined margins. There was at the time a faint light in the north, but there was no other auroral appearance with which this beam could be confounded. As an opportunity so favorable as this for definite observation on an auroral phenomenon rarely occurs, I endeavored to note its exact position, with the time, and now publish the results in the hope that they may meet the eye of other observers.

At 9h 25m mean time New Haven, the auroral beam stands up from the westerly horizon, about one degree wide, cutting with its southerly edge the star Castor, and extending up to and terminating at the star 38 Lyncis. There is nothing of the kind visible at a greater altitude, or in the east. Towards the easterly horizon, however, the view is obstructed by clouds and buildings.

The whole beam slowly moved southward, but during the brief period of observation the change of position in the basal portion was scarcely perceptible.

At 9h 31m the southerly edge cuts rau and epsilon Geminorum, and also Pollux. All above, the star last named has faded: the sky is becoming hazy in this quarter, and the light of the beam rapidly fading.

During this period the beam has been wholly isolated. There are still some auroral indications on the northern horizon, without any special activity. My time was certain within thirty seconds, and the beam moved so slowly that an error of even a minute would be of little importance.

Beams of light such as that described above have often been noted during earthquakes and as part of the Andes glow.

GLA-030 [WRIGGLING STREAM OF LIGHT]

Anonymous; Nature, 68:627, October 29, 1903.

A correspondent, referring to Prof. W. H. Everett's letter on rocket lightning in our last issue, directs attention to a closely similar phenomenon observed in London between 2 and 3 a. m. on the morning of October 16. From the south-eastern horizon of a clear sky, a "wriggling stream" of bluish-white light shot up in a vertical direction and broke off short without spreading. It would be interesting to know if any other observer witnessed this display, and if a thunderstorm occurred that night anywhere to the south-east of London within twenty or thirty miles.

Everett's letter is to be found in vol. G3.

GLA-031 AURORAL PHENOMENA AT ALTA, IOWA

Hadden, David E.; Popular Astronomy, 10:249-251, 1902.

About nine o'clock in the evening of March 29th, 1902 a bright auroral beam was observed in the southeast sky at an altitude of about 30 degrees.

When first seen it was more or less obscured by light clouds and its true nature was hard to determine. It was a perpendicular, pale narrow streak of light, about 5 degrees in length and about one-half degree in width, with the star in the constellation Virgo, almost exactly in the middle of the beam. About 20 minutes later the clouds cleared away and the beam was a beautiful object, resembling strongly a fine comet of a pale greenish-white light, ten minutes later it reached its maximum brightness when it was a deep yellow to orange color and had moved about a degree farther north. Underneath, towards the horizon was a dark region, above which was a faint auroral glow. Five minutes later the phenomenon disappeared and did not appear again.

Its position in the southeast quadrant of the sky was unusual, and many people supposed the light to be a comet.

It is a noteworthy coincidence that a large bright region of faculae was observed nearly at the east limb of the Sun in north heliographic latitude 30 degrees, the following day.

During the past twelve years a large number of auroras have been observed and studied at this station, and during the years of increased sunspot activity, the frequency and brilliancy of the auroral displays were much augmented.

In looking over my observing note book I found a number of instances where auroral beams with little or no motion were observed, and as such phenomena have been often mistaken for comets by the public and amateurs, a short account of those I observed may be of interest.

On the night of July 13th, 1892 following a brilliant display of Northern Lights, a superb beam of greenish light resembling a long narrow fish was visible from Coma Berenices to Leo Major and remained stationary until it gradually faded out.

July 16, 1892, a beam of light spread athwart the sky from northwest to southeast which was nearly stationary.

On July 15th, 1893 a bright beam of light stretching from the northwest sky to Lyra near the zenith, was supposed at the time by many newspapers and some astronomers to be some remarkable change in comet b which was discovered about a week previously, and was receiving much attention by the press and public.

On the night of May 3rd, 1899 a fine comet-like beam of light was observed in the northwest sky at an altitude of about 18 degrees, this resembled very much the photographs of Brooks' comet of 1893.

June 28th, 1899 bright comet-like beams of light were visible in the northeast sky at a height of about 45 degrees, later, swiftly moving parallel bars were observed near the same region.

On January 20th, 1900 following a slight auroral display in the northern sky, a fine, bright beam of light extended horizontally from the west to south horizon at a height of about 18 or 20 degrees.

In nearly all the above cases Northern Lights either preceded or followed the beam phenomena, but in the case of the streak seen recently, no disturbance was at any time to be seen in the northern sky at this station.

In Monthly Notices, Vol. 56 for March 1896, Professor H. H. Turner, Sir W. J. Herschel, W. H. Robinson and others call attention to a curious light

seen in England on March 4th of that year, which they supposed to be the zodiacal light, probably owing to its position in the western sky, and the direction of the streak which, if prolonged, would pass through the Pleiades.

In Knowledge for April and May 1896, a number of correspondents also refer to the same phenomenon, and variously ascribe it to the zodiacal light, a meteor track or Sun pillar. There is no doubt in my mind from the descriptions given and the behavior of the light that it was one of the numerous manifestations of the aurora.

In Nature for March 28th, 1896 Dr. Brauner, of Prague, calls attention to luminous streaks observed by him on the 13th of the same month, and under the heading "Some Luminous Appearances in the Sky" in Publications of the Astronomical Society of the Pacific, Vol. IX, No. 54, W. H. S. Monck gives an account of a number of instances in which similar streaks of light were reported by various observers, and were mistaken for comets, meteors, etc., and which the author does not feel satisfied were auroral.

In looking over the U. S. Monthly Weather Review for March 1896, I find that the dates on which the number of reports of auroras especially exceeded the average were March 4th, 6th, 11th, 13th, and 14 and this would seem to indicate conclusively that the lights were auroral in character and that while the displays were typical Northern Lights over wide areas, in other places, probably dependent on local conditions, peculiarities in the shape of streaks and beams of light prevailed.

The subject is interesting and worthy of careful observation and study on the part of amateur and professional astronomers and meteorologists.

GLA-032 OBSERVATION OF OPTICAL PHENOMENA AT SIRAH ISLAND, ADEN, 7 OCTOBER 1957

Hirst, N. F. ; Meteorological Magazine, 87:278, September 1958.

At 1915 hours local time a very pale green glow was observed in the southern sky, over the Indian Ocean. The glow was marked by a very faint ill-defined boundary about 25 degrees above the southern horizon lowering to about 20 degrees on the south-western horizon. It was impossible to see the southern horizon as vision was obscured by rocks rising to about 600 feet high. The phenomena lasted from approximately 1915 (when it was first observed) to 2130 hours when it faded completely. About 2125 hours a russet-coloured band of light was observed low down on the southern horizon just before the glow faded completely. Throughout the whole period there were occasional rays of light mostly orange in colour at infrequent intervals. These never rose to above 3 degrees above the southern horizon. Stars in the sky at about 15 degrees above the horizon were seen to be changing colour quite frequently (mostly red and green). At times the colour of the stars was observed to be particularly bright, predominantly green. The glow was at its brightest between 1915 and 1930 hours but after 1930 hours the glow was observed to brighten occasionally for periods not exceeding five minutes. The weather at the time was fine. There was a bright moon almost overhead. There was no cloud, a light wind and the sea was practically calm.

GLB-076 [ROD-SHAPED BALL LIGHTNING]

Gaddis, Vincent H. ; Mysterious Fires and Lights, David McKay Co., New York, 1967, p. 54.

In most reports, ball lightning performs silently, but sounds are sometimes heard. In 1959, Mrs. Lillian Mack, of Kansas City, Missouri, was in her home durinh an afternoon thunderstorm when she heard a sound like "crushing glass." An object about two feet long and one inch in diameter came flying like a spent arrow into the room where it hovered while forming the shape of a ball. After a minute, it dissolved, and "while dissolving we all heard the sound of breaking glass.. .but no glass was broken... sparks flew from the falling dust-like stuff and the (object) looked like hot metal.

GLB-077 FIREBALLS

Petrie, W. M. Flinders; Nature, 30:360, August 14, 1884.

The following account I have received from a lady at Bruhl near Cologne, July 26;—"8.22. A large fireball of scarlet fire almost as large as a harvest moon just sailed along and upwards, at a varying but most very rapid rate, until, at a great height, it remained for some minutes almost or quite stationary; then after some uncertain movements rose again, and rising, became smaller until it finally disappeared_____Every one who saw it seemed petrified with amazement. " This is of interest from the long time that the ball was visible, and its being seen by several people . . . . .

While living lately at San (Tanis), thirty-two miles south-west of Port Said, there occurred a most remarkable thunderstorm on May 12, lasting from 1.15 till 4 p. m. . . . . .The thunder was not in loud, reverberating peals, but was a continuous rushing, gusty, swishing sound; the noise rising and falling just like a gusty, tearing, high wind, without any crashes or explosive bursts, and with very little bumping or knocking sounds. It only lightened once or twice during that half hour, and there was but a faint breeze of wind. To the best of my belief the thunder was similar during the whole time of the storm, though with more explosive sounds and more lightning in the early part, It is impossible to refer such a storm to the ordinary instantaneous, sharp discharges with echoes, as the sound had no character of a reverberation; it appears to be due to a continuous discharge like that from a point. The storm was quite local, only extending a few miles. Since returning to England I have also heard thunder which was apparently not from an instantaneous discharge, as it began lightly and waxed louder for two or three seconds, until a loud crash of the main discharge took place. . . . . .

The latter descriptions resemble those of "slow" lightning found in GLL.

GLB-078 EXTRAORDINARY ATMOSPHERIC PHENOMENON

Hannay, J. B. ; Nature, 25:125, December 8, 1881.

GLB-079 BALL LIGHTNING

J. B. Hannay transmitted the following paragraph from the Glasgow Evening Citizen of November 25, 1881:

> Those on board the Campbelton Steamer Kinloch (Capt. Kerr), which left Greenock on its usual run about half-past eleven o'clock on Tuesday morning after the storm that raged during the night, had a somewhat extraordinary experience while passing down the Firth. The vessel was enveloped in a dense shower of hail, and for some time it was awfully dark, and occasionally the vessel was lit up by vivid flashes of lightning. One of the flashes was very bright, and its shape was something like that of the arteries of the human body, with a central column all shattered and broken. About noon, while opposite the Cloch Lighthouse, and not far from the shore, the captain observed immediately over the ship what appeared to be a series of clear balls of lightning, each about a foot in length, and resembling a chain, except that they were disconnected. This phenomenon was quickly succeeded by an explosion in the funnel of the steamer, and several balls of fire upon the bridge running about, and then bounding off into the water. The first impression of the spectators was that something had exploded on board, but on inquiry it was founa that this was not the case. The mate stated, however, that a ball of lightning had almost struck him where he stood. A fireman rushed upon deck to see what had happened, as the engine-room was filled with smoke, and a choking sensation was experienced below. The explanation appears to be that a portion of the lightning had passed down the funnel until its force was spent by the fire, and the sudden recovery of the draught of the funnel afterwards accounted for the loud report that was heard. The captain, in his long experience at sea, never encountered such a phenomenon before, and it may be taken as an indication of the extraordinary atmospheric forces which had been at work during the storm, and which seemed to centre in this locality.

GLB-079 NOTICES OF EARTHQUAKE-SHOCKS FELT IN GREAT BRITAIN ....

Milne, David; Edinburgh New Philosophical Journal, 31:92-122, 1841.

The balls of fire noted in the following entries from Milne's catalog may have been true ball lightning or possibly meteors. The detonations and whizzing noises are heard with both phenomena. Even the electric shocks felt in the Derby incident are ascribed at times to both ball lightning and meteors.

> 1750 ; England. The sound preceding the concussions, resembled the discharge of several cannon, or distant thunder in the air, and not a subterranean explosion. Flashes of lightning were observed an hour (before?) and a vast ball of fire. . . . .Near London, there was continued and confused lightning till within minute or two of shock; dogs howled; fish jumped three feet out of water; sound in air, preceded concussions; flashes of lightning and a ball of fire were seen, just before explosion, (p. 98)

> November 18, 1795; Leeds, Bristol, Norwich, England. Immediately before shock, a whizzing gust of wind. A tremulous motion in the earth preceded and followed the shock. The barometer for thiry-six hours preceding the shock, had varied remarkably, —on 17th, it was 30.23. On 18th it sunk to 28.63; and just before the shock it was 28.8. . . . .[In Derby and Nottingham] A ball of fire was seen to pass over the town of Derby, when the shock was felt. The Rev. Mr.

Gregory relates that about six hours before the shock his "attention was much struck with the aspect of the sky in the S. and SE. quarters. In this direction, a cloud very black and lowering extended itself over this part of the hemisphere. The margin of the cloud, which was nearly parallel to the horizon, was fringed, to the extent of at least 40°, from the S. towards the E., and to the breadth, perhaps, of 11/2°, with a very bright light, which had very much the appearance of white satin. The light was shaded, to its whole extent, as it were with a veil of'a deep muddy purple colour. The white light, seen below this gloomy purple haze, and farther contrasted by the very dark surface of so extensive and lowering a cloud formed a very striking appearance. "—"I was fully persuaded that this luminous appearance was occasioned by electric light, with which I concluded the cloud to be highly charged." At 8 P. M. "every extraordinary appearance had now vanished, the night was dark and gloomy, the air quite calm and mild. At ll' 20- we were all extremely surprised and alarmed at a sudden blast (rather than explosion, because it had not that sharp compressed elastic tone I annex to the idea of an explosion) which burst out instantaneously somewhat below the zenith to the W., and which, as I conjectures from the direction in which the sound was heard, seemed to rush through the air towards the E. with great velocity, and to meet with considerable resistance to its motion; for it made a whizzing noise as it passed over us. At the instant the blast burst out, it was "accompanied with a very loud, deep-toned, hollow, sullen sound, not altogether unlike a deep groan. "— "The first shock felt to me so tremulous, that I could not form any judgment concerning its direction; my chair was shaken with a kind of vertiginous motion. The second shock seemed to come from the N., perhaps a few points to the W. of it."

Another gentleman at Derby, though he did not observe the meteor before mentioned, "perceived at the instant of the concussion, a remarkable coruscation proceeding from the SW. quarter of the heavens, and producing a gleam similar to a distant flash of lightning, but of longer continuance."

Many persons at Derby "felt something like an electrical shock." (pp. Ill—112)

GLB-080 A PECULIAR LIGHTNING PHENOMENON

Winchester, George; Science, 70:501-502, November 22, 1929.

The author relates how on August 28, 1929, near Peoria, Illinois, he and his brother were in a car in a thunderstorm when a brilliant flash of lightning took place. The car was shaken and the occupants felt an electric shock

The flash appeared to be just on our right in an open pasture crossed by what was once an osage hedge, but now only a few small trees of that hedge remained at intervals of twenty to thirty feet. About six feet from the trunk of one of these hedge trees we observed a ball of smoke about two feet above the ground. The ball appeared to be about eighteen inches in diameter and perfectly spherical. The color of this smoke, if it was smoke, was a yellowish brown quite similar to the smoke given off by burning straw. The ball began immediately to diffuse into the surrounding air just as the smoke from an exploding shell.

Three days later, they returned to the spot to look for evidence of the lightning discharge but found nothing.

GLB-081 BALL LIGHTNING

GLB-081 OF SPOTS BEFORE THE EYES

Mauer, Edgar F.; Science, 116:693, December 19, 1952.

At the height of the flying saucer craze, Mauer, a medical doctor, wonders if flying saucers might not originate in the eye of man. Spots or motes before the eye (called muscae voliantes) are shadows cast upon the retina by cells normally found in the vitreous fluid. The spots are stimulated by exposure to uniform bright surfaces and even digestive disorders.

Anyone who has observed this visual phenomenon will recall that the object seen is brilliant and that it moves erratically, its erratic motion being a compound effect related to the motion of the shadow on the retina and associated movements of the eyeball and head. These objects also agree with some "observations" made on flying disks in that it is impossible to judge their distance or speed.

Another visual phenomenon which may be observed in the dark, as well as in the daylight, is the scintillating scotoma. Scotomata may be of various colors but otherwise are of uniform appearance as judged by the descriptions given by many persons suffering from migraine. They are of fairly consistent duration, usually lasting about 20 min, with an initial period of increasing density, then of stable appearance until they fade away. They are thought to be of cerebral origin.

It is thus likely, in the opinion of the writer, that flying disks are motes in the eyes of a dyspeptic microcosm or perhaps some abnormal cortical discharges in the migrainous.

These comments apply to ball lightning and other bright luminous phenomena.

GLB-082 BALL LIGHTNING AND PLASMOIDS

Silberg, Paul A.; Journal of Geophysical Research, 67:4941-4942, November 1962. (Copyright by the American Geophysioal Union)

In a discussion of ball lightning, Hill [1960J suggests that the duration of the luminosity of a fireball is one of the more important considerations. Moreover, he suggests that if no outside source of energy is present a plasma state could not exist for longer than a few milliseconds at most. It is not completely clear how this conclusion is arrived at, since no theoretical considerations of the decay mechanisms of the plasma state were presented.

It is, therefore, of interest to report a fairly well known and documented 'fireball' phenomenon that is occasionally and accidentally formed aboard certain types of U. S. submarines. This phenomenon corresponds in some ways to some of the phenomena reported as ball lightning (which may form in a similar fashion).

In submarines there are usually two sets of batteries and two generators to charge them. The generators are connected through a reverse current relay, and they 'disconnect' in such a manner that either generator can be connected to either battery bank. The main contacts of the circuit breaker are made of silver, with conventional copper extensions and a blow-out coil.' At times, a

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highly charged battery bank has been accidentally connected across a 'dead' generator. The reverse current relay then disconnects the circuit. An arc is usually formed across the silver electrodes, and the blow-out coil directs the arc onto the copper electrode extensions to minimize the silver electrode erosion. Usually the arc is 'blown-out.' However, when the amount of charge left in the batteries creates a sufficiently intense current through the arc, a green fireball will 'float' off the contacts into the engine room. The lifetimes of these plasmoids are of the order of a second. The green color is attributed to the copper from which the extensions of the silver electrodes are made. No appreciable damage has been reported from these 'engine-room plasmoids.' However, it has been established that a threshold of current or power is required before a plasmoid will form.

During the 'Guppy Reconversion Program' in 1947 at the Philadelphia Naval Shipyard, tests were performed on the reverse current gear of the U. S. S. Cutlass (Hull SS478), and a fireball was generated in the engine room using 260 volts and 156,000 amperes direct current. This gives a peak power of about 40 megawatts. Switching times of the order of 0.1 to 0.01 second are standard with mechanical switching, so that an energy of the order of 0.4 to 4 megajoules is the estimated energy range in which this plasmoid forms. The estimated diameter appears to vary between 4 to 6 inches or from 10 to 15 cm.

The remainder of the paper discusses the computation of the energy density of ball lightning.

GLB-083 THE DANCING SUN

Osborne, Charles; Catholic World, 169:208-215, June 1949.

This is an excerpt from a description by a Miss Gordon of the famous "Miracle of Fatima," October 13, 1917, in Portugal.

'The Cova da Iria, I must tell you" (Miss Gordon was well warmed up to her subject now, and the others never breathed a word) "is a large basin-like hollow in the mountains——you know it well," she said, addressing her host, "and when we got there it was packed with people, thousands and thousands of them——they say there were 70,000—and just as we arrived somebody told them to close their umbrellas which most of them did. I thought this was mad for it was still raining hard——they must have got as drenched as I was. It was terribly dark. The clouds were thick in the sky and there seemed to be no sign of a break in the weather.

"Then suddenly every head seemed to be looking in one direction, straight upward——and all at once the rain stopped——I remember particularly this sudden stoppage of the rain. It was uncanny. Just as if someone had turned off a tap in the sky——then I saw the clouds tear apart." Miss Gordon fumbled for words to try to make her meaning clear.

"Yes—they tore apart," she continued. "They didn't just break as usually happens after a storm, it was as if two hands had clawed a big hole in the clouds leaving an expanse of blue -sky, and in the middle of it the sun appeared. But it was not exactly like the sun——it was just as bright as the sun is on a fine day but

this time you could look straight at it. We all did. It was the color of stainless steel——like that knife there." And Miss Gordon picked up one of the knives on the table and contemplated it for a moment. "Just like that, but very, very bright."

"Well, this was queer enough, but I remember thinking that it wasn't worth coming all that way to see. I was still feeling rather miserable and soaking wet. But we continued looking up and then I thought I saw the sun turning around on itself. How can I describe it?" Again she chose her words carefully. "Well, like a giant Catherine wheel, first slowly, then increasing until eventually it spun around at a terrific rate and began to throw out great beams of light, all different colors. The rocks and the ground and the people looked ghastly. Some were blue, others green and orange and red, every color of the rainbow. I rubbed my eyes. I shut them and opened them again——but it was still the same, and everybody else seemed to be seeing it too. My companions and those around me were just as amazed as I was.

"This lasted for about five minutes——I'm not exaggerating——and then the sun stopped. We exchanged ideas with the people in the crowd about us. Nobody could give a reasonable explanation. 'It's a miracle,' they all said, 'a sign from God.' Then while we were talking and becoming very excited, the sun started again. Once more it began to spin round on itself——to dance, as the people all around me were calling it, and then, after about four or five minutes it stopped again. This time, I was sure I had not been mistaken. And then, while I was trying to figure it all out in my mind, the sun, for the third time, began to revolve. Then suddenly, the sun which all this time had been a peculiar silver color changed into a deep blood red and while keeping its swift rotation...."

At this point, Miss Gordon, who all the time had sat with downcast eyes as if addressing the plate before her on the table, and without the slightest effort on her part to impress her audience, suddenly became animated and standing up and stretching her arms to their full height, she made as if she held a large football in her cupped hands which she tugged away from its moorings in the atmosphere and brought down on the heads of her audience.

"The sun," she went on, "blood red in color, seemed to detach itself from the firmament and came hurtling down on the heads of the people present. They thought the end of the world had come, and so did I. It was a terrifying moment. Pandemonium broke out. Everybody was shrieking at once, calling for mercy and pity. Many of the women present were crying out such things as 'Stop the War,' 'Give us Peace,' 'Send my husband home again,' 'Bring our boys back.' It seemed to me that the crowd, at any rate those around about where I was standing, were seized with panic. Some fell on their faces in the mud, praying out loud, 'God save me,' 'Mother have pity on us,' and so forth. Others were praising God and our Lady. But it didn't have that effect on me. I never was a very emotional person, but it happened just as I have described it to you. I saw, without the slightest doubt, the sun dance.

"Altogether, these events took from twenty minutes to half an hour and finally the sun which had seemed to fall on the heads of the crowd, getting bigger and bigger in size as it fell, climbed back again in the same zigzag fashion, and then shone out as it normally does on a clear day. The clouds broke up quite naturally, and for the rest of the day the weather was fine.

"One peculiar thing which I noticed as did many other people to whom I spoke was that our clothes which had been soaking wet were suddenly made dry, leaving us with a pleasant, comfortable feeling.

"I'm afraid the miracle of the sun didn't make must impression on me. It happened, right enough, and that I can swear to, but the thing that effected me most was having my clothes dried for me. But then you see, I'm not an educated person and I don't know much about these things."

It took the other three some few minutes to realize that the story was finished. Then, they all wanted to fire questions at Miss Gordon at once.

"Couldn't it have been mass hysteria, or a mass optical illusion?" asked Charles.

"I thought that at one time, " broke in the lawyer, who had obviously heard the story before, "but I found out that this solar phenomenon was also seen by many people in many different places, some of them as far as ten miles away, so that seems to rule that out."

"The most remarkable thing to me, " put in Margaret, "is the fact of anything happening just as those three children said it would. What I mean to say is that leaving aside the nature of the miracle, it does seem odd that something should have happened which those little children foretold three months earlier, giving the exact date and time, so that the vast crowd of people turned up to see it. I do wish you would tell us more about that."

Miss Gordon was about to reply when their host answered for her:

"Oh, you'll find all that in the books on Fatima, " he said. "I'll give you a copy of one tomorrow, and you'll see that the whole story revolves round these children to whom our Lady appeared in six successive occasions in 1917, giving them various messages concerning the state of the world at that time and the fate awaiting men if they did not amend their lives. There's a terrific amount in it which we cannot go into now, but the miracle of the sun was performed to prove to those 70,000 people present that our Lady did appear to the children and that they were not repeating some story out of their imagination.

In addition to the psychic aspects, the luminous object also had a strong resemblance to ball lightning and modern so-called "UFOs. "

GLB-084 LIGHTNING STRIKE 23 APRIL 1964

Vidler, G. T. ; Meteorological Magazine, 93:254, August 1964.

During the afternoon of Thursday, 23 April 1964, a Varsity aircraft of the Meteorological Research Flight, Farnborough, was flying in a large cumulo-nimbus situated south of Bedford. The base of the cloud was at 2500-3100 feet with patches of stratus at 1200 feet A thunderstorm was in progress with frequent lightning and heavy rain. At 1410 GMT, when the aircraft was at 3000 feet in heavy rain just below the cloud base, a brilliant flash of white light and a loud bang was observed. The inside of the aircraft was then illuminated with a shimmering whitish-blue light for a couple of seconds from the starboard side.

The pilot, on the other hand, reported that the loud bang momentarily preceded the flash. He then saw a ball of blue light about the size of a football on the starboard wing tip. This ball lasted for about two seconds before vanishing.

There were several more flashes of lightning, but none in the immediate vicinity of the aircraft.

After landing, a number of small burns were found on both the starboard and port wing tips and also on the underneath of the fuselage. The navigation light on the starboard wing tip had been smashed and the aircraft compass when tested indicated an error in reading of about 10 degrees.

GLB-085 BALL LIGHTNING

GLB-085 REMARKABLE METEOROLOGICAL PHENOMENA IN AUSTRALIA

Jensen, H. I.; Nature, 67:344-345, February 12, 1903.

On Wednesday, November 13, 1902, we experienced here in Australia some most extraordinary meteorological phenomena. For the previous five or six days, exceedingly hot, dry weather had prevailed, owing to winds blowing from the Australian interior, where a huge anticyclone was resting, in a coastward direction, the winds taking in Queensland and New South Wales a westerly, and in Victoria a northerly, direction. The hot weather culminated in terrific dust-storms in Queensland, New South Wales, Victoria and South Australia, and during these storms "fireballs" were seen hovering in the air. On the sea, "red rain" was experienced by several passing vessels.

The following is an abstract of what happened:-

Melbourne, Wednesday, November 13. Weather phenomenal, great heat, dust-storms, in all parts of Victoria.

At Boort, great fireballs fell in the street, throwing up sparks as they exploded. The whole air appeared to be on fire; intervals of complete darkness; lanterns had to be used in daytime, and fowls went to roost.

At Longdale, a house set on fire by a fireball.

Balls of fire burst on the poppet heads of the New Barambogie mine, Chiltern, Victoria, putting the timbering of the shaft on fire. Almost every meteorological station in Victoria sent in similar reports—fireballs, darkness in daytime, and people stumbling about with lanterns.

Sydney. On November 14, Mr. Bruggman, of Parramatta, was paralysed by a fireball bursting over his head.

Harden, Wednesday, November 13, During a storm yesterday at Murrumburrah, a huge "fireball" hovered over the houses for a considerable time and then disappeared.

GLB-086 [VIOLET BALL SURROUNDED WITH RAYS]

Anonymous; Nature, 42:458, September 4, 1890.

The Caucasus papers relate an interesting case of globular lightning which was witnessed by a party of geodesists on the summit of the Bohul Mountain, 12,000 feet above the sea. About 3 p.m., dense clouds of a dark violet colour began to rise from the gorges beneath. At 8 p.m., there was rain, which was soon followed by hail and lightning. An extremely bright violet ball, surrounded with rays which were, the party says, about two yards long, struck the top of the peak. A second and a third followed, and the whole summit of the peak was soon covered with an electric light which lasted no less than four hours. The party, with one exception, crawled down the slope of the peak to a better sheltered place, situated a few yards beneath. The one who remained was M. Tatosoff. He was considered dead, but proved to have been only injured by the first stroke of lightning, which had pierced his sheepskin coat and shirt, and burned the skin on his chest, sides, and back. At midnight the second camp was struck by globular lightning of the same character, and two persons slightly felt its effects.

Obviously electric discharge effects accompanied the "ball lightning."

GLB-087 IN SUPPORT OF A PHYSICAL EXPLANATION OF BALL LIGHTNING

Wittmann, A.; Nature, 232:625, August 27, 1971.

The purpose of this communication is to present additional evidence in favour of the exclusion of explanations of ball lightning in terms of, (a) the retinal afterimage hypothesis, (b) the intense point discharge hypothesis and (c) the burning material hypothesis. Altschuler lists these in his summary of possible explanations.

During a dinner on the evening of July 6, 1971, at Orselina, near Locarno, Switzerland, I observed a flash of lightning which struck an unidentified target near the roof of a building about 200 m away. An intense point discharge immediately followed the flash and was visible clearly at the target for 1 or 2 s. I immediately told the other people at the dinner (Professor E. H. Schroter and Dr. E. Wiehr from Gottingen and Mr. C. Kuhne from Oberkochen) of my observation because they were not looking out of the window at the time.

This occurrence was unmistakably different from another lightning event, which I observed several years ago and which I consider to have been a rare event of actual ball lightning. At that time a thunderstorm accompanied by heavy rain took place in the area of Neustadt near Coburg, Germany. I was sitting with some other people (among them Mr. C. Forster from Berlin) right behind a ground floor window so that I could look at the weather; the field of view out to the street was limited by the frame of the window. Suddenly, at a height of about 16 m above the ground and at a short range of about 24 m, I saw a spherical plasma ball coloured bright yellow-white. This object appeared to have a diameter of 50 to 100 cm. It moved vertically downwards with a speed of about 4 m a , and its path ended in the top branches of a tree, at a height of approximately 9 m. On touching the tree the ball instantly disintegrated into eight to twelve smaller spheres. These were the same colour as the large one and each had a diameter to 12 to 15 cm. They fell to the ground, guided by the outer contour of the tree, and moved vertically during the last few metres in the absence of branches. On reaching the ground (an asphalt roadway and a neighbouring footpath) the spheres instantly disappeared. There was no noise apart from that of the rain and no lightning associated with the primary plasma-like sphere. Three to five minutes afterwards, the same phenomenon occurred again in precisely the same way as before, indicating that the conditions needed to produce and guide the primary sphere were still maintained or re-established during the time that had elapsed. Immediately after the rain had stopped, I went out into the street to look for further evidence. There were circular patches of melted asphalt on the wet asphalt cover of the roadway which showed the interference colours of this layers. Their diameters were each 12 to 15 cm and they obviously marked the impact areas of the smaller spheres. This event was described similarly by all the witnesses.

Because roadway asphalt in general contains B-80 bitumen——a thermoplast from which liquid components disintegrate at about 170°C——one may very roughly calculate the minimum amount of energy needed to produce the observed patches. Assuming that a water layer of thickness 0.5 mm at 20°C was evaporated and that an asphalt layer of thickness 1 mm was then heated to 170°C, and assuming a mean density of 1.0 g cm^{*3} and a mean specific heat c_p = 0.46 calorie g$^{"1}$ for B-80, one may easily calculate the energy density of the plasma spheres to be at least 1.9 x 10^{7} J m$^{\sim 3}$.

Again, fragmentation of ball lightning is observed and computations indicate very high energy densities.

GLB-088 BALL LIGHTNING

GLB-088 GLOBULAR LIGHTNING

Ryan, G. M. ; Nature, 52:392, August 22, 1895.

On June 21, about 6 p. m., Dr. Wallis, Mr. Taylor and myself were in our drawing-room on the ground floor, taking shelter from a passing storm; they were seated, and I stood five paces from them. The doors were all closed against the storm, and I went out and, for cool air, opened one. On returning, I saw a globular light, about the size of the full moon in the air between Wallis and Taylor, and almost instantly I heard in the room a terrific clap of thunder like a cannon. I suffered afterwards from acute pain down the left side of my face. Taylor, who had an iron-headed golf stick in his hand, felt a twinge up his right arm, and a sensation as of singeing in his hair. Wallis felt nothing at all. We all experienced a sulphurous smell. In the adjoining room, leaning against one corner, were two Martini-Henry rifles in leather cases. One was untouched. The stock of the other was almost shattered, splinters lying about the room. The leather covering of the splintered rifle was torn, but the metal part of the rifle quite unhurt. At the point of the wall where the muzzle of the shattered rifle touched the wall, there was a hole 5 x 2-1/2 and 1-1/2 to 2 inches deep. The wall is of mud and plaster. In the room above were two holes in one wall; that is, the wall above that in which the hole appeared below. These holes were smaller than the one below. Just below the two holes stood a wooden case, iron-bound, and at its foot the matting was torn up, but the floor and the case were untouched. In the second room above, that is, the room over that in which I had seen the globular lightning, the wall near the ceiling was cracked for six or eight feet. This was all the damage done that we could find.

GLB-089 BALL LIGHTNING

Wooding, E.R. ; Nature, 199:272-273, July 20, 1963.

Wooding suggests that ball lightning may be a vortex ring of plasma.

GLB-090 AN OCCURRENCE OF 'BALL LIGHTNING'

Falkner, M. F. ; Meteorological Magazine, 93:95, March 1964.

On the evening of Wednesday, 6 November 1963, at approximately 11. 5 p. m. my father saw in his bedroom, in the centre of the room, a small, egg-shaped ball of brilliant light. Within the space of a few seconds, this small ball of light spread itself to form a sheet of darkish green light as wide as the room itself (approximately 12 feet). This curtain of light then moved towards my father and turned greyish colour. The whole sight then vanished as suddenly as it appeared, with a very loud bang, similar to the report from a rifle. The light was witnessed only by my father but the bang was heard by both my brother, from a neighbouring bedroom and my mother, who was downstairs in the kitchen. The bedroom light was on and it was raining at the time. We would not believe that this phenomenon had occurred if it were not for the fact that the very loud bang was heard by three people who were each in different rooms at the time.

GLB-091 BALL LIGHTNING

Finkelstein, David, and Rubinstein, Julio; Physical Review, 135:390-396, July 20, 1964.

Abstract. A plasmoid model for ball lightning is examined. The usual virial theorem shows that confinement by self-field alone is inconsistent with conservation laws for energy and momentum; a generalization shows that the presence of air pressure removes this inconsistency and gives an upper bound to the stored energy. This upper bound is much less than the energies reported for some occurrences. For permissible energies the kinetic temperature and density of the plasma can be chosen so that it will not be degraded by internal Coulomb collisions or dissipated by cyclotron radiation for some seconds. It is however necessary to insulate the plasma from the air. A self-field that is able to do this will give up the total stored energy to ohmic heat in the air boundary in a much shorter time than is reported. It is concluded that the plasmoid model is impossible and that energy must be supplied to the ball during its existence if the order of magnitude of the reported energies and times are accepted. Therefore a new model is examined. The high dc electric fields associated with lightning storms are invoked as energy source, and an idealized nonlinear conduction problem is shown to admit ball-like solutions. This leads to a ball lightning model of a low-current glow discharge in an atmospheric dc field, A region of higher conductivity results in a local increase of the electric field and current density sufficient to produce a glow discharge, which provides the higher conductivity and is thus self-consistent. If this model is appropriate, then ball lightning has no relevance to controlled-fusion plasma research.

GLB-092 A SO-CALLED THUNDERBOLT

Lodge, Oliver J. ; Nature, 46:513-514, September 29, 1892.

During a short storm in Liverpool this summer, I noticed one flash as peculiarly sharp and noisy, and subsequently in the correct bearing from my house the ground was reported as having been struck by a thunderbolt. I examined the place, which was on the greensward of a lake, where the ground was penetrated by a number of fairly clean-cut almost vertical holes down which a walking-stick could be thrust. People sheltering near the lake reported a ball of fire and a great splash up of the water. The odd circumstance about the damage was that it occurred on a simple grass slope, about half way between a tall boat-house on the one side and a drinking fountain standing on more elevated ground on the other. Small trees also were in the neighbourhood, and there was no apparent cause why the flash should have selected this particular spot; though indeed it was not within any of the ordinarily accepted "areas of protection." A gentleman——Mr. Hewitt——proposed digging for the meteor, and although fairly convinced that it was nothing but an ordinary flash, we thought it just possible that an accidental meteorite might have fallen during the thunderstorm; in which event a flash down the rarefied air of its trail would be a natural consequence. It may be just possible that the popular belief in thunderbolts has some such foundation.

At any rate the excavation was made, with the result of proving that it was an ordinary flash and that the lightning made use of a surface drain-pipe, about four feet deep, to get at the water of the lake.

GLB-093 BALL LIGHTNING

GLB-093 OPTICAL AND ACOUSTICAL DETECTION OF BALL LIGHTNING

Wagner, Gunther A.; Nature, 232:187, July 16, 1971.

The recent controversy about ball lightning stimulates me to report an observation of such an event, which occurred in September 1963.

This event occurred at approximately 11 a. m., in the entrance hall of the Plockenhaus, a restaurant below the Plockenpass in the Carnic Alps (Austria). Students from a field trip of the Geology Department of the Universitat Heidelberg were staying inside this restaurant because of a thunderstorm with heavy rain. Some of the students were sitting in the guest room and some were standing in the entrance hall. The outside doors of the house were open. The door between the guest room and the entrance hall was, as I remember, closed. The floor of the entrance hall consists of heavy limestone plates. Also in the entrance hall was a St. Bernard dog, lying on the floor.

Suddenly, through the open outside doors, a whitish yellow ball appeared just above the floor. It was slightly larger than a tennis ball, and its speed was about that of a walking person. The light ball moved about 2 m in the direction of the dog and finally exploded with a loud bang, like a gun shot. The dog jumped away as it saw the moving light ball. All the people in the entrance hall (about five) saw the ball and heard the bang. People from the guest room came out to ask what happened, because they had heard the bang. I do not remember feeling any radiation heat from the bang, nor smelling anything after the explosion. We, the bystanders, explained this event as a "Kugelblitz" (ball lightning).

The optical observation by several people, the reaction of the dog, and the acoustic perception of the people in the adjacent room are hard to explain by the optical illusion hypothesis for ball lightning.

GLB-094 [TAPERED BALL LIGHTNING]

Anonymous; Nature, 46:548, October 6, 1892.

A curious instance of globular, lightning is referred to in the Meteorologische Zeitschrlft for September 1892. On August 7, during a thunderstorm at Altenmarkt, near Furstenfeld, while the priest was administering the sacrament, the church was struck by lightning, followed by a loud explosion. A panic immediately ensued, and the congregation rushed out, notwithstanding the assurances of the priest that there was no danger. There was nothing to show how the lightning entered the church, but it is supposed it was by the conductor leading from the steeple. It is said to have been a large globe, tapering towards the upper part, and after the explosion it left a strong sulphurous smell. The explosion was very loud and shook the building.

GLB-095 BALL LIGHTNING

Jensen, J. C.; Physics, 4:372-374, October 1933.

This article is essentially identical with that GLB-016 with the addition of some spectacular photographs.

GLB-096 LIGHTNING

Goodlet, B. L.; Institute of Electrical Engineers, Journal, 81 1-26, 1937. (A lengthy discussion of the paper by various authors follows the paper proper.)

Only that portion of the paper and those comments relating to ball lightning are quoted below. See GLL-031 for more of this article.

(f) Ball and Bead Lightning. Ball lightning is sometimes regarded as a subjective phenomenon. Although the accounts of many eye witnesses are undoubtedly imaginative, there is a mass of evidence to show that it really does occur. Recently Dr. Walther Brand of Marburg collected some 600 accounts of ball lightning, of which 215 were sufficiently detailed to inspire confidence in their accuracy. From these 215 accounts Dr. Brand deduced the principal characteristics of the phenomenon. A translation of his summary is given below.

(i) Ball lightning (also termed a fireball or thunder bolt) is a ball-shaped (occasionally pear-shaped) electrical discharge of long duration which occurs occasionally during thunderstorms. Ball lightning occurs most frequently towards the end of a thunderstorm and is more frequent in winter. Its activity is less than that of ribbon lightning.

(ii) Ball lightning generally appears as a red luminous ball of 10-20 cm. diameter surrounded by a blue contrast region and with a hazy outline. The balls may, however, be a blinding white and the outline is sometimes quite sharp.

(iii) A hissing, humming, or fluttering noise is usually heard.

(iv) On disappearing, fireballs often leave a sharp-smelling mist, which appears brown by transmitted light, blue by reflected light, and white when the air is saturated.

(v) The duration of the phenomenon varies from a fraction of a second to several minutes. The most usual duration is 3-5 sec.

(vi) A fireball may appear by descending out of the base of a cloud; it may also form as a floating ball, in free air or attached to some object. Very often ball lightning is preceded by an ordinary lightning flash, in which case the ball appears at or close to the point struck; this initial flash is, however, often absent.

(vii) Fireballs may disappear silently, with a mild crack, or with a blinding explosion——when a number of short streamers shoot out of the ball in all directions. Occasionally the ball is extinguished by an ordinary lightning flash striking It.

(viii) The velocity of a fireball which falls from the cloud base to the ground is very considerable (transition to ordinary lightning); close to the ground or in closed rooms fireballs usually move at about 2 metres per sec. A fireball may remain stationary for a time and an "attached" (aufsitzende) fireball can remain, boiling and emitting sparks, in its initial position until it disappears (transition to St. Elmo's fire). Sometimes a fireball appears to be moved by an air current but in general its movement is independent of the wind.

(ix) Occasionally several fireballs appear round a place which has been struck by ordinary lightning. A single large fireball may burst into several smaller ones. Very occasionally two balls appear one above the other, bound together by a string of smaller balls, or such a string may appear attached to a single fireball [transition to true bead lightning (perlschnur blitz)].

(x) "Floating" (freischwebende) and "attached" (aufsitzende) fireballs appear to behave quite differently, although they can change into one another. Floating balls suggest a discharge of high voltage and small current; attached

balls suggest a discharge of lower voltage but large current.

(xi) "Floating" fireballs have the red colour of meteorite tracks in the lower atmosphere. They shun good conductors and generally choose a path through good conductors and generally choose a path through the air. They are attracted towards closed spaces (i. e. houses) which they enter through the open window or door, sometimes even through small cracks; the chimney, with its conducting but non-inductive gases, is a favourite path, so that fireballs frequently appear in the kitchen from out of the fireplace. After circling the room several times the fireball leaves by some air path, often the one by which it entered. Floating ball lightning is not dangerous to human beings even when it appears in the middle of a group of persons; it appears to avoid them like it avoids good conductors. Occasionally a fireball makes two or three vertical oscillatory movements with an amplitude from a few centimetres to several metres. When these vertical oscillations are combined with a translatory motion the ball appears to progress in hops. Often the motion is confined to a single descent from the clouds to within a few metres above ground, followed by an immediate re-ascent.

(xii) "Attached" fireballs are of a blinding brilliance and white or blue in colour. They attach themselves to good conductors, preferring the highest points, or roll along such conductors (e. g. roof gutters) They heat the objects to which they are attached or along which they roll. They cause severe burns on the human body when they move over it (occasionally under the clothes) and produce lethal effects.

(xiii) The transformation of a "floating" into an "attached" fireball usually occurs by its making a dart to a good conductor in the vicinity. On touching the conductor it may either disappear, quietly or with an explosion, or it may continue as an "attached" fireball. Fireballs which fall from the clouds usually hit the ground and explode.

(xiv) The transformation of an "attached" into a "floating" fireball occurs by the ball simply rising from its support and floating upwards, usually along an inclined path, towards the clouds. In general such balls are extinguished very shortly afterwards.

No satisfactory theory of ball lightning has so far been developed. As the phenomenon cannot be observed at will it is likely to remain a mystery for some time to come. The most reasonable speculation is probably that of Prof. W. M. Thornton——that a fireball is a mass of ozone produced by the discharge, which suddenly reverts to oxygen with explosive violence. Other theories are discussed in Brand's book and in a series of papers by E. Mathias.

Bead lightning is a relatively well-known phenomenon. A recent letter published in Nature states that in one case 20 to 30 beads about 3 inches in diameter and spaced about 2 ft. apart lasted about half a second after an intense flash. This account is typical, (pp. 10-11)

Written comments submitted by engineers and scientists follow:

For many years I have held the opinion that the "balls" of ball lightning are masses of nitrogen oxides formed by the lightning. On various occasions I have published the idea, e. g. in a letter in the Yorkshire Post of the 20th October, 1923. In this paper under discussion there are three references to the colour of the ball: (1) ball lightning generally appears as a red luminous ball; (2) fireballs often leave a sharp-smelling mist, which appears brown; (3) floating fire-

balls have the red colour of meteorite tracks in the lower atmosphere. Surely these are confirmations. Quite obviously the balls are not electric, for the paper says "Floating ball lightning is not dangerous to human beings even when it appears in the middle of a group" but later it says "They heat the objects to which they are attached or along which they roll. They cause severe burns on the human body when they move over it." I suggest that the reference to the sharp-smelling mist and to the action of the ball on the body confirm the explanation I have suggested, namely that the ball is a mass of nitrogen oxides. Yet the author says "No satisfactory theory of ball lightning has so far been developed," and then goes on to refer to a speculation of Prof. W. M. Thornton "that a fireball is a mass of ozone produced by the discharge." In other words, Prof. Thornton goes part of the way; why not the whole way, I cannot understand, for ozone will not explain the colours and will not explain the burning effect, whereas nitrogen dioxide does explain them both. In the References and in some footnotes the author mentions articles and letters which have appeared in Nature, but he makes no reference to what I maintain is the very reasonable explanation that I gave in Nature of the 24th November, 1923.

Mr. S. J. Rust suggests that earthquakes may be more closely connected with radioactivity than is generally accepted, and emanations may increase the potential of atmospheric electricity very considerably. The following are some interesting side issues on this question: (1) Attempts at increasing rainfall, or staving off hail, by gunpowder explosions (at which scientists have laughed) may be at times partially successful, because they upset the electrical equilibrium of the air. (2) At the beginning of the War, certain newspapers attributed the abnormal rainfall to the firing of cannon, but later there was dry weather without cessation of the firing. This may be explained if we attribute the rainfall to electrical disturbances effective at the beginning of operations, but reacting as the cannonading becomes habitual. (3) The old country notion that a meteorite is a thunderbolt has been ridiculed, but a meteorite rushing to earth at a time when an anticyclone has given hot dry weather, and an electrified atmosphere, may upset the electrical equilibrium sufficiently to produce a storm. (Comment by E. Kilburn Scott, p. 31)

Last summer we had an experience of a floating fireball at the works adjoining my office. The ball came slowly out of a closed room which has 2-ft. walls on all three sides and is used as a drying stove. It was pear-shaped and of a dull red colour, and as it floated lazily out of the door of the drying stove, across a wooden landing and over the top of a motor lorry, there were short streamers of red flame coming out from it in all directions. Eventually, when it reached about 3 ft. from the ground, it burst with a tremendous bang. By this time the rain had started. Simultaneously with the appearance of this fireball the circuit breaker on the lighting system was tripped and there was an outbreak of fire. This occurred on the opposite side of the 2-ft. wall from the room where the fireball had come through, at a point where the lighting wires passed within a few inches of the lightning conductor coming down from the mill stack. I made a very careful examination afterwards but I could find no sign of anything having gone through the wall into the room where the fireball started, yet I feel sure there must have been some connection between the two. (Comment by A. B. Mallinson, p. 46)

GLB-097 BALL LIGHTNING

GLB-097 A SO-CALLED THUNDERBOLT

Hewitt, George H.; Nature, 46:514, September 29, 1892.

During a thunderstorm on the afternoon of Sunday, July 3, 1892, what is described as a "ball of fire" was seen by several persons to descend to the ground, near the south end of the lake in Sefton Park; and immediately afterwards a column of water, about sixty feet high, was shot up from the lake. On examining the spot where the ball of fire was seen to descend, several clean-cut holes were observed, and a sod was also found at a little distance from the spot.

A few days afterwards an excavation was carefully made. The sod being removed, the holes were traced down to a surface drain pipe four feet below the surface. At this drain the holes terminated, and the pipe was found shattered. The important holes were found to be six, the largest being seven inches in diameter, the others about two inches. No meteoric matter was found, but it seems curious that this effect was brought about by a flash of lightning only, in an open space of sloping grass, when there were trees and houses close by.

GLB-098 TOWARD A THEORY OF BALL LIGHTNING

Lowke, J. J., et al; Journal of Geophysical Research, 74:6887-6898, 1969.

Compiler's Summary: This is a highly theoretical paper with essentially no observational data. The authors surmise that ball lightning may be a plasma initiated by ordinary lightning.

GLB-099 [BOUNCING BALL LIGHTNING]

Anonymous; Nature, 46:62, May 19,, 1892.

Science of April 29 prints the following account of a fireball, by C. C. Bayley:- "A telephone wire was supported on cedar posts 20 feet high and 20 rods apart. During August, 1889, we had a thunderstorm, during which there was a sharp and heavy crash. Several of the poles were found to have been struck, and portions to have been taken out through their entire length. One of these portions, of the size of a medium rail, was thrown into an adjoining field some rods from the pole. Portions from the others were smaller and more or less shattered. Near the southernmost pole struck, a family were in a house with doors and windows open, and a luminous ball seemed to leap from the wire, pass through the open door and a window, and pursue its course some rods through the open space behind the house. A boy in the room grasped his thumb and cried out, 'I'm struck, ' and Mr. Hewett felt a sensation of numbness in his left arm for some time. A girl seized her shawl and rushed out of the house to chase the ball. She reported that she pursued it some distance, while it bounded lightly along, until it seemed to be dissipated in the air without an explosion. The size of the ball was about that of the two fists, and its velocity about that of a ball thrown by the hand. "

GLD-045 SUMMER LIGHTNING

Geikie, Arch. ; Nature, 68:367-368, August 20, 1903.

Although a good deal has been written on the subject of "summer lightning, " it may not be superfluous to describe a display of the phenomenon which occurred here last evening on a scale far surpassing anything which it had been my good fortune to witness before. There had been several thunderstorms in the district during the previous five or six days, and a few peals were heard and heavy rain fell in the early afternoon of the day before (August 13). But the sky cleared rapidly thereafter, and the evening and night of that day were cloudless, every peak and crest standing out sharply defined in the clear air. Yesterday was still fine, but warmer and less bracing than visitors here expect. Late in the afternoon wisps of white mist began to gather round the summit of the Jungfrau, and streaks of thin cloud took shape in the higher air above the great mountain ridge that extends from the Silberhorn to the Breithorn. About 8 p. m I noticed a faint quivering light overhead, supplemented by occasional flashes of greater brilliance and different colour. These manifestations rapidly increased in distinctness, and continued to play only along the opposite mountain-ridge, not extending into the regions beyond, so far as these could be seen from here, though I have since learnt that an independent series of flashes was seen around the Schilthorn on this side of the valley Not a single peal of thunder was at any time audible. A long bank of cloud formed at a higher level than the summits of the mountain-ridge, and at some distance on the further side of it, so that the stars, elsewhere brilliant, were hidden along the strip of sky above the crest.

As one watched the display it was easy to distinguish more definitely the two kinds of discharge. One of them took the form of a faintly luminous reddish or pink light, which shot with a tremulous streamer-like motion in horizontal beams that proceeded apparently from left to right, as if their starting point lay somewhere about the back of the Jungfrau. These streamers so closely resembled the aurora borealis that, had they appeared alone, one would have been inclined to wonder whether the "northern lights" had not here made an incursion into more southern latitudes. So feeble were they when they sped across the clear sky that the stars were clearly visible through them. Sometimes they quivered on the far side of the cloud, lighting up its edges and sheeting beyond it across the still unclouded blue. At other times they appeared on this side of the cloud, and showed the dark outline of the mountains in clear relief against the luminous background. They so rapidly succeeded each other that they might be said to be continuous, a faint pinkish luminosity seeming to remain always visible, though pulsating in rapid vibrations of horizontal streamers.

The brighter discharges were not only far more brilliant, but much more momentary. They had a pale bluish-white colour, and came and went with the rapidity of ordinary lightning. But they were clearly connected with the mountains, and not reflections from a series of distant flashes Sometimes they arose on the other side of the great ridge, allowing its jagged crest to be seen against the illuminated surface of the cloud beyond, but leaving all the precipices and slopes on this side in shade. In other cases they clearly showed themselves on this side of the mountains, lighting up especially the snow-basins and glaciers with the dark crags around them. Nothing, of the nature of forked lightning was observed among them In one instance the flash or horizontal band of vivid light, a mile or two in length, seemed to shoot upward from the slope at the base of the precipices of the Silberhorn, as if it sprang out of the ground, having a sharply defined and brilliant base, rapidly diminishing in intensity upward, and vanishing before reaching half-way up to the crest.

But the most singular feature of the more brilliant white discharges was to be seen when one of the great couloirs of snow or a portion of a glacier remained for a minute or two continuously luminous with a faint bluish-white light. After an interval the same or another portion, perhaps several miles distant, J would gleam out in the same way. My first impression was that this radiance f could only be a reflection from some illuminated part of the cloud. But I could not satisfy myself of the existence of any continuously bright portions of the cloud. Moreover, the luminosity of the snow and ice remained local and sporadic, as if the beam of a search-light had been directed to one special part of the mountain declivity, and then after a while to another. While watching one of these patches of illumination, I noticed a bright point of light at the top of one of the basins of neve on the slopes of the Mittaghorn. It quickly vanished, but soon reappeared, and then as rapidly was lost again. I thought that it was probably a star briefly exposed through rifts in the cloud, though its position seemed rather below that of the mountain-crest. Half an hour later, however, a similar bright light appeared about the same place, more diffused than the first, and having a somewhat elongated shape. Whether it was really a star seen through the distorting medium of a wreath of mist, or a form of St. Elmo's fire clinging to some peak on the precipice, could not be ascertained from its momentary visibility

I learnt this morning that other observers who could watch at the same time the mountain ridges on each side of the Lauterbrunnen valley noticed that sheet-lightning was also playing about the Schilthorn, but quite independently of that on the Jungfrau range, the one mountain being dark, while the other was illuminated. The distance of the two electric centres from each other is between five and six miles. The whole display last evening afforded an admirably complete demonstration of the erroneousness of the notion formerly prevalent that summer lightning is only the reflection of distant ordinary lightning, and of the truth of i the more recent views as to the nature of the phenomenon.

I may add that, as the lightning increased, the air, which had previously been nearly calm, freshened into a strong breeze, which blew from the south-west down the valley, but died down after the illumination faded away. The cloud above the mountain began to assume irregular dark cumulus shapes, and the sky became generally overcast. JSarly this morning rain was falling heavily. The mountains have been all day shrouded in dripping cloud, and the deluge still continues.

Geikie seems to describe electric discharge effects rather then "lightning" per se. As with the Andes Glow, there seems to be a similarity to auroral phenomena. The place was Murren, Germany, August 14, 1903.

GLD-046 LIGHTNING OBSERVATIONS BY SATELLITE

Sparrow, J. G., and Ney, E. P. ; Nature, 232:540-541, August 20, 1971.

This paper presenting data taken by the OSO-2 and OSO-5 satellites also contains hints of electrical action high above the earth under the heading "spurious events."

On some occasions apparent "lightning strokes" were detected that could not be assigned as such because at the time the fields of view of the telescopes were well above the Earth. Some of these were detected by as many as three

photometers simultaneously when the photometers were looking above the satellite. The decay time indicates that the signal probably originated forward of or in the photomultiplier preamplifier systems. Because the electronics
k associated with each photomultiplier are isolated from each other (although
W sharing the primary spacecraft power) it is unlikely that these apparent increases are electronic in nature. Furthermore, if the increases were initiated by feedback through the spacecraft batteries then all six photometers would probably show similar effects. This has occurred at other times when noise is present in the data but in these cases the characteristic time constant is not seen in each photometer signal. On the occasions under discussion, only those photometers viewing in the anti-sail direction and not those viewing in the opposite direction have been affected. The possibility of spurious reflexions from the front light baffles of each photometer (for example, from lightning meteors and so on) can probably be eliminated because of the large attenuation in the scattered signal compared with the direct signal when the photometers view close to the Moon. The distribution of these signals over the Earth's surface is approximately random, suggesting that the source is not lightning. Single occurrences are seen about once every ten orbits. No acceptable mechanism has yet been found to explain these anomalous data spikes.

These increases, which seem to be due to short duration (-C 0.1 s) "light" flashes, arise from processes other than lightning and must be eliminated from the data before any discussion of lightning distribution can be entered into. This has effectively been done by accepting as storms only those occasions when two or more strokes were observed. In this way some seventy occasions when one stroke only was seen simultaneously by the two telescopes——when their fields of view were on the Earth——have been eliminated.

^Since the satellite's instruments could not measure distance, the flashes might have been nearby or deep in the earth's atmosphere.

GLD-047 [CLOUD OF FIRE]

Anonymous; London Times, November 30, 1825.

A very remarkable meteorological phenomenon too place on the 3d of this month in the forest of Calenhoven, in the arrondissement of Thionville. A waggoner, returning from Sierck to Filstroff, was passing through the forest between six and seven o'clock in the evening. He arrived within three quarters of a league of Laumesfeld, when, during a violent storm, accompanied with thunder, the forest appeared to be suddenly on fire from one extremity to the other, and continued so for a quarter of an hour. The horses being terrified, became violently restive, and one of them breaking his harness, took flight and ran to the village, where, being met by several persons, they conjectured some accident had befallen the conductor. They proceeded immediately to the forest, and on approaching it perceived a cloud of fire traversing the horizon in a direction from north to south. The most dense and profound darkness succeeded this apparition. The waggoner whom they were in search of, responded to their calls, and was discovered in such a state of terrible apprehension, that some time elapsed before he could recover himself sufficiently to answer their questions and explain the cause of his horror.—-Journal de Moselle.

GLD-048 ELECTRIC DISCHARGE

GLD-048 [STRONG LUMINOSITY, PECULIAR CLOUDS]

Anonymous; Nature, 32:375, August 20, 1885.

At about midnight on July 29 a remarkable phenomenon was seen at Jonkoping (Sweden), over lake Wettern. A strong luminosity was suddenly seen in the north, where some very peculiar clouds—looking like icebergs—were seen almost to touch the water. From these clouds electrical discharges continually proceeded, imparting to them a bluish, phosphorescent light, somewhat ruddy near the water and intensely yellow at their sides. It seemed like a constant discharge of fireworks from the lake. It was remarkable that the light—as is generally the case with an electrical discharge in the atmosphere—did not assume the form of bunches of streamers, but at one time flared up intensely and at others formed narrow bands across the clouds. Above the latter there was a faint bluish reflection. The lake lay as calm as a mirror, and though an optical illusion was uncommon in these parts, the western shore seemed close to the town, while the eastern disappeared in the clouds. Except the electricity-laden clouds in the north the sky was clear, stars shone, and the full moon was bright. Below the latter the sky seemed faintly red, compared with the intense electric light. At Katrineholm the same phenomenon was seen in the northeast. Here an intense glare was seen above a cloud, assuming the appearance of two gigantic lustrous trees, which remained thus for half an hour, when it changed into a variety of forms. There was no noise accompanying the phenomenon, which lasted in both places for about one hour. It is not probable that the phenomenon could have been of auroral nature on account of the brightness under a full moon.

GLD-049 [EARTHQUAKE LIGHTS]

Anonymous; Nature, 90:550, January 16, 1913.

Shortly after the great Valparaiso earthquake of August 16, 1906, attention was directed to certain luminous phenomena that were observed before, at the time of, and after the earthquake. The observations have recently been analysed by Count de Montessus de Ballore, the director of the Chilean Seismological Office (Bollettino of the Italian Seismological Society, vol. xvi., pp. 77-102). The total number of records collected is 136. Of these 44 are decisively, and 16 implicitly, negative; in 38 cases some lights of an indefinite character were noticed; in the remaining 38 records the observation of luminous phenomena is more or less explicit. Many of the negative records are communicated by persons accustomed to scientific investigations, and in some cases contradict alleged observations of lights at the same places. It does not follow that the lights, when observed, were connected with the earthquake, for, in the centre and south of Chile, a storm rated during the night of the earthquake, and it was from this part of the disturbed area, and not from the epicentral district, that most of the observations came. Count de Montessus therefore concludes that, for the Valparaiso earthquake at any rate, the connection of the luminous phenomena with the earthquake is not proven.

GLD-050 EARTHQUAKES AND THEIR CAUSES

Lake, John J.; English Mechanic, 21:51-52, April 2, 1875.

Lake firmly believed in the electrical nature of earthquakes and quoted the following observations to prove his point.

The earthquakes of 1692, in Jamaica, and 1693, in Sicily, present very strong evidences of general electric disturbance in the globe at those times. One evening in February, 1692, at Alari, in Sicily, the village seemed to the country people to be in flames. The fire, as they imagined, began by little and increased for about a quarter of an hour, when all the houses in the place appeared to be enveloped in one flame which lasted about six minutes and then began to decay, as from want of more fuel. Many who ran to render assistance, observed this increase as they passed along the road, but on entering the village found all to be a delusion. Such appearances of fire and light occur in other localities subject to earthquake, e.g., at Cowrie, Perthshire, one morning before daybreak, in 1842, the light is stated to have been so brilliant that birds were distinguished on the trees. Again in Sicily, about the 15th of May, following the incident at Alari, two hours before sunset, the atmosphere being very clear, the heavens appeared on a sudden all on fire, without any flashes of lightning or the least noise of thunder. This lasted at Syracuse about a quarter of an hour, when there appeared in the air over the city two bows, the colours extremely bright, after the usual manner, and a third with the extremities inverted, and, as not a single cloud was visible in any part of the sky, the abnormal state of the atmosphere is clear. It was also during this summer that the unusually severe thunderstorm occurred at Geneva that so materially affected the future career of the celebrated Robert Boyle. The earthquakes at Jamaica began on the 17th June, and their greatest violence seems to have been spent in the mountains. Terrific noises were heard amongst them at Port Royal during the last shock, and they were so torn and rent as to present a very shattered appearance and quite new forms. In this month Etna emitted extraordinarily loud noises for three days together. A singular circumstance during this catastrophe at Jamaica was the derangement of the wind. The land-breeze often failed, and the sea-breeze blew all night, whereas the land-breeze should blow all night, and the sea-breeze all day. There was an earthquake on the 8th September, 1692, in Europe, but I have not yet been able to find out the locality.

Space will not admit or more than noticing some special phenomena of the Sicilian earthquakes, 1693. On the 10th of January the Castle of Augusta was blown up by the lightning firing the power magazine. At Minco, on the 11th, the shock was attended by "a mighty storm of lightning, thunder, and hail that lasted six hours." The Archbishop's palace at Monreal was set on fire by the lightning. Etna emitted great noises, flames, and ashes, during the shocks that overthrew Catania, but there does not appear to have been an eruption. Furia, situated amongst limestone quarries, disappeared, and at several parts of the hill the rocks, which were previously almost as white as Geneva marble, had changed, and in the clefts made by the earthquake had become of a burnt colour, as if fire and powder had been employed to rend them asunder. Millitello seems to have been destroyed before the 11th of January, for the country people, who dwelt on the neighbouring ridge of mountains, affirmed that it was not to be seen on the morning of that day, to which time, from 12 o'clock on the 8th, it had been concealed in a thick fog. During the interval the mountain that lay on the north side of the town had been split asunder——one portion overwhelming Millitello, so that not an inhabitant escaped. Francofonte, built chiefly of wood,

escaped with little damage from the shocks, but was fired by lightning; the spire of the church——wood covered with lead——burnt down, and the nunnery of the Carmelites entirely destroyed so suddenly, that five of the nuns were stifled in their beds. The largest part of the inhabitants of Luochela escaped by flying from the town on the sudden disappearance of the castle, situated on a rising ground. Ragusa experienced shocks on the 8th with violent thunder and lightning. At Specufurno, on the 10th, "from morning till night, there was never heard so violent a storm of thunder and lightning, as if heaven and earth had been mixing together;" the townhouse and several other houses were destroyed by it. The peasants on the neighbouring hills observed that this lightning had burnt the vines so that no crop could be expected for the season.

The earthquake of London, 1749, also exhibited strong symptoms of electric action. The year abounded with thunder and lightning, coruscations frequently appeared in the air, and the aurora removed to the south, showing upon two occasions unusual colors. Dr. Stephen Hales heard a rushing in his house which ended in an explosion in the air as from a small cannon, and attributed it to the escape of the fluid by the steeple of the church of St. Martin's-in-the-Fields, adjoining. The Rev. J. H. Murray refers to the electrical disturbances on the east coast of South America, contemporaneous with the great earthquakes on the west coast in 1868, and considers them related. He describes one storm, just at the time of the earthquake, as giving "an idea of what the bombardment of Sebastopol must have been like."

The phenomena of seaquake are of a similar character. We have ourselves seen electric clouds thrown into auroral forms contemporaneously with the disturbance of the sea at another locality.

Examples might be extensively multiplied, but the above would seem sufficient to show that a leading cause of earthquake is electric action, and that volcanoes sometimes produce the same by direct convulsion, and at others by disturbing the electric equilibrium of a locality, (p. 52)

Another portion of this article is presented in GQE-012.

GLD-051 METEROLOGICAL PHENOMENON

Mackenzie, T.; Nature, 33:245, January 14, 1885.

Leaving the port of Kingston, Jamaica, at dusk on November 23, 1885. the night was fine and starlit overhead, but about 8 p. m. a heavy bank of cloud obscured the island, and all around the upper edges of this cloud-bank brilliant flashes of light were incessantly bursting forth, sometimes tinged with prismatic hues, while intermittently would shoot vertically upwards continuous darts of light displaying prismatic colours in which the complementary tints, crimson and green, orange and blue, predominated. Sometimes these darts of light were projected but a short distance above the cloud-bank, but at others they ascended to a considerable altitude, resembling rockets more than lightning. This state of matters continued until about 9. 30 p. m. , when all display of light ceased. As I have never seen such a phenomenon in any other part of the world, I have deemed it an unusual occurrence, and worthy of record.

GLD-052 TORNADOES: PUZZLING-PHENOMENA AND PHOTOGRAPHS

Shepard, Roger N., et al; Science, 155:27 + , January 6, 1967; and 155:1037, February 24, 1967. (Copyright 1967 by the American Association for the Advancement of Science)

Different eyewitnesses seem to have given rather similar accounts of "Luminous phenomena in nocturnal tornadoes" (Vonnegut and Weyer, 9 Sept., p. 1213 [GLD-015], and of certain types of so-called unidentified flying objects." J. Vallee's book on "UFO's," Anatomy of a Phenomenon (Regnery, Chicago, 1965), for example, includes a number of reports of slow-moving or stationary, often "cigar-shaped," objects or "clouds" with some or all of the following,characteristics: vertical orientation; surrounding smoke or luminous haze, or multicolored or rotating lights; smaller, brightly luminous balls or disk-shaped objects that typically emerge from the lower end of the larger object and then fall or drift toward the ground or veer away——sometimes apparently at great speed. Sometimes, but not always, such a phenomenon is described as making its initial appearance out of a bank of clouds. Similarly, in connection with tornadoes, Vonnegut and Weyer's witnesses speak of such things as a vertical luminous column, a blue halo or rotating lights, "orange balls of fire" issuing from the bottom or "cone point" of the elevated funnel, and even a bright white, blue and yellow basketball-sized object floating along 5 feet (1.5 m) above the ground. Isn't it possible, then, that these phenomena associated with tornadoes, previously described instances for "ball lightning," and at least some sightings of alleged "UFO's" or "flying saucers," all reflect basically similar sorts of electrical disturbances in the atmosphere? (Roger N. Shepard)

. . . . In Weyer's photo of "unusual illuminated vertical pillars," the fact that the power and phone lines crossing the foreground also appear lighter in the area of the "pillars," plus the fact that he did not observe the pillars visually while making the exposure suggests that these streaks are due to nonuniform application of the developer, such as sometimes happens when single rolls are developed in small tanks, the developer being poured in after the film has been inserted.

To me, the pillars appear to extend down into the immediate foreground, but the perception is almost subliminal. If the film were mine, I would make a lighter print of much higher contrast. If this caused the extension of the pillars into the immediate foreground to become fully evident, I would conclude that the pillars were caused by developer and not by tornadoes. Many "flying saucers" originate in the darkroom as the result of such processing accidents. But sometimes foreground material is present which also shows a change in gamma where it crosses the light blob that has been identified as a flying saucer, and so identifies the blob as a processing fault.

Nonetheless, this was a fascinating article! (William R. Wells)

Our initial reaction, upon being shown a photographic print of the illuminated vertical pillars by Edmond Dewan, was probably that of most readers: that the effect could quite easily be an artifact either of exposure or processing. On reading of the guillotine method of exposure, a number of possibilities suggested themselves for the presence of an exposure artifact, such as, a background light passing through the gaps between the fingers, or reflected light from a ring on one of the fingers. This latter situation looked very possible in view of the stray illumination present from a window adjacent to the one through which the exposures were made. Obviously studying the print

could only lead to fairly empty speculation and any real conclusions could only be based on tests conducted on the original negative. Later Vonnegut made the original negative available to us for densitometric study and the results indicate that the luminous pillars are not an artifact but a real exposure. We can, of course, say nothing about the nature of the occurrence of the pillars.

A strip of film was loaned to us containing the interesting frame 11 plus frames on either side. The pillars existed only in the normal frame area of the film and did not extend outside this as they might have if caused by a light leak in the camera, or from certain types of faulty development techniques. No similar phenomena existed in any of the other frames.

The bright pillar on the left hand side of the photograph appears to cross the frame down to the region of the houses. We conducted a densitometric study, using an isodensitracer of this and other regions of the negative. In the iso-densitometer is coded into a repeating series of symbols. The three-symbol cyclic code consists of a segment of a line, a series of closely spaced dots, and a blank space. Hence the direction of the change in density can be determined unambiguously. Once the scan is completed, the instrument automatically steps over a predetermined distance and rescans along a line parallel to the first scan. This process is repeated over the area of interest. When the set of scans is completed, the contours of equal density in the negative are readily recognizable. The interpretation can be greatly assisted if the dash-dot-space code is repeated in four different colors.

Figure 1 (top) shows the area that was traced and (center) shows the resultant plot. Both the photograph and the trace are 20x enlargement. The pillar of light reaches down to the roof line but does not depress the contours of the roof as it would if the pillar extended in front of the houses. Figure 1 (bottom) shows a 200x trace of the region including the roof and chimney. Again the flatness of the roof contours is apparent. The intersymbol density difference is 0. 01 density units and the scanning aperture is 100 Apparently the pillar goes behind the house or stops suddenly at the roof line. The latter explanation is just too unlikely especially since the roof line is not flat. Any faulty exposure or development technique would not give this result.

A further detailed study was made of the structure of the two luminous pillars. Figure 2 shows the trace at 20x with a density increment of 0. 012 and with a 100-jj2 aperture. The appropriate portion of the photograph at the same magnification is shown for comparison. The wires do cross the pillars but are not resolved at this scanning aperture size. Structure is apparent in the pillar with a maximum high up.. A similar result is apparent in the other pillar of light on the right hand side of the photograph as indicated in Fig. 3.

The indications are that the luminous pillars constitute a genuine exposure and are not an artifact of either exposure or development. Unfortunately no information was available concerning the characteristic curve of the film so that the brightness distribution of the pillars cannot be determined quantitatively. However, qualitatively the information in Figs. 2 and 3 is meaningful. Could the luminous pillars be caused by reflected ground-based lights? The maximum in each pillar looks too high up for that. This short note indicates the validity of the pictures and shows the usefulness of this particular desitometric technique in quantizing photographic density for the study and evaluation of photographic results. Of course, this work can give no indication of the nature or cause of the pillars. (Brian J. Thompson and Ronald H. Johnson)

The intermittent luminosity occurred after the tornado had developed; therefore, it seems to be a side effect rather than a cause. The partial vacuum in the eye of a tornado (which is capable of lifting an automobile) provides the path of least resistance for electricity between the overhead storm clouds and the

earth. It might act as an enormous vacuum tube, somewhat similar to a geissler, neon, or fluorescent light tube, conducting very low density electric current wherever there is a sufficient accumulation of electricity in the clouds to make the jump to earth. The discharge is reported to last only a few seconds; also, some observers were within the luminous area with no ill effects.

The partial vacuum in the tornado, together with the difference in potential between the earth and clouds, appears to be the direct cause of this illuminated path of the discharge. It is conceivable that spiraling supersonic winds in the eye of the tornado actually throw the air from the center toward the wall of the core so hard that additional vacuum is produced in the center. This augments the partial vacuum produced by the thermodynamic process at work in the system. (Samuel Blakeslee Roberts)

Early ideas similar to Roberts' were advanced by Robert Hare in 1840 when he was professor of chemistry at the University of Pennsylvania. In discussing the tornado problem, he offered a translation of suggestions made by Peltier, the French physicist fAmer. J. Sci. and the Arts 38, 73 (1840)1:
. . . .Flashes and fiery balls of sparks accompanying the tornado, a smell of sulfur remains for several days in the houses, in which the curtains are found discolored. Everything proves that the tornado is nothing else than a conductor formed of the clouds which serves as a passage for a continual discharge of electricity from above.

While we hope that eyewitnesses will continue to report in as great detail as possible what they see at the time of a tornado, we think it is clear that the most important thing that needs to be done is to obtain good photographic evidence of what is going on. It is our own opinion that we have certainly not established that the photograph indeed represents the two tornadoes, but it seems that an atmospheric phenomenon of some kind is probably present and that further studies are desirable. (Bernard Vonnegut and James R. Weyer)

GLD-053 SEEING THE INSIDE OF A TORNADO

Justice, Alonzo A. ; Monthly Weather Review, 58:205-206, May 1930.

Although the incidents herein set forth occurred nearly two years ago, it is thought that they are sufficiently interesting to be reported even at this date. It was just 16 months to a day from the time the events happened that the writer heard a direct account of them from the man whose extraordinary experience forms the basis of this story.

Mr. Will KeUer, a farmer of near Greensburg, Kans., is the man to whom reference is made, and the following is substantially his story:

It was on the afternoon of June 22, 1928, between 3 and 4 o'clock. I was out in my field with my family looking over the ruins of our wheat crop which had just been completely destroyed by a hailstorm. I noticed an umbrella-shaped cloud in the west and southwest and from its appearance suspected that there was a tornado in it. The air had that peculiar oppressiveness which nearly always precedes the coming of a tornado.

But my attention being on other matters, I did not watch the approach of the cloud. However, its nearness soon caused me to take another look at it. I saw at once that my suspicions were correct, for hanging from the greenish-black base of the cloud was not just one tornado, but three.

One of the tornadoes was already perilously near and apparently headed directly for our place. I lost no time therefore in hurrying with my family to our cyclone cellar.

The family had entered the cellar and I was in the doorway just about to enter and close the door when I decided that I would take a last look at the approaching tornado. I have seen a number of these things and have never become panic-stricken when near them. So I did not lose my head now, though the approaching tornado was indeed an impressive sight.

The surrounding country is level and there was nothing to obstruct the view. There was little or no rain falling from the cloud. Two of the tornadoes were some distance away and looked to me like great ropes dangling from the clouds, but the near one was shaped more like a funnel with ragged clouds surrounding it. It appeared to be much larger and more energetic than the others and it occupied the central position of the cloud, the great cumulus dome being directly over it.

As I paused to look I saw that the lower end which had been sweeping the ground was beginning to rise. I knew what that meant, so I kept my position. I knew that I was comparatively safe and I knew that if the tornado again dipped I could drop down and close the door before any harm could be done.

Steadily the tornado came on, the end gradually rising above the ground. I could have stood there only a few seconds but so impressed was I with what was going on that it seemed a long time. At last the great shaggy end of the funnel hung directly overhead. Everything was as still as death. There was a strong gassy odor and it seemed that I could not breathe. There was a screaming, hissing sound coming directly from the end of the funnel. I looked up and to my astonishment I saw right up into the heart of the tornado. There was a circular opening in the center of the funnel, about 50 or 100 feet in diameter, and extending straight upward for a distance of at least one half mile, as best I could judge under the circumstances. The walls of this opening were of rotating clouds and the whole was made brilliantly visible by constant flashes of lightning which zigzagged from side to side. Had it not been for the lightning I could not have seen the opening, not any distance up into it anyway.

Around the lower rim of the great vortex small tornadoes were constantly forming and breaking away. These looked like tails as they writhed their way around the end of the funnel. It was these that made the hissing noise.

I noticed that the direction of rotation of the great whirl was anticlockwise, but the small twisters rotated both ways——some one way and some another.

The opening was entirely hollow except for something which I could not exactly make out, but suppose that it was a detached wind cloud. This thing was in the center and was moving up and down.

The tornado was not traveling at a great speed. I had plenty of time to get a good view of the whole thing, inside and out. It came from the direction of Greensburg, which town is 3 miles west and 1 mile north of my place. Its course was not in a straight line, but it zigzagged across the country, in a general northeasterly direction.

After it passed my place it again dipped and struck and demolished the house and barn of a farmer by the name of Evans. The Evans family, like ourselves, had been out looking over their hailed-out wheat and saw the tornado coming. Not having time to reach their cellar they took refuge under a small bluff that faced to the leeward of the approaching tornado. They lay down flat on the ground and caught hold of some plum bushes which fortunately grew within their reach. As it was, they felt themselves lifted from the ground. Mr. Evans said that he could see the wreckage of his house, among it being the cook stove, going round and round over his head. The eldest child, a girl

of 17, being the most exposed, had her clothing completely torn off. But none of the family were hurt.

I am not the first one to lay claims to having seen the inside of a tornado. I remember that in 1915 a tornado passed near Mullinville and a hired man on a farm over which the tornado passed had taken refuge in the barn. As the tornado passed over the barn, the door was blown open and the man saw up into it, and this one like the one I saw, was hollow and lit up by lightning. As the hired man was not well known, no one paid much attention to what he said.

After leaving the Evans farm it continued to "bounce" (as one witness described it) its way across the eastern half of Kiowa County and was last heard of in Pratt County. It left a path here and there where it struck the ground, not of wrecked buildings, for there were no more buildings in its path after the Evans farm, but of torn-up ground. It tore holes and plowed furrows from a few inches deep to several feet deep.

Mr. Corns said that he saw a furrow which it plowed across a field of wheat. The furrow was from 2 to 3 feet wide and as deep as the ground had been plowed, about 6 inches. The dirt was thrown over on each side of the furrow just as it might have been if a plow had made it.

A farmer whose land had been marked by the tornado said that it made a furrow "deep enough to bury a horse in."

Mr. William Cobb, resident of Greensburg and owner of a number of farms in Kiowa County, said that the tornado crossed one of his pastures of buffalo-grass sod and that it plowed a furrow a mile long in places from 4 to 6 feet deep, and that the whole thing looked like "where there had been a grading for a railroad." The dirt was piled along the side of the furrow, just as if thrown there by hand or plow or dragged there by scrapers. It was reported that farmers used scrapers and horses to level up the ground where the tornado had disturbed it.

The excavations formed by this tornado indicate extremely concentrated and intense forces.

GLD-054 TORNADOES AT BLACKWELL, OKLA., MAY 25, 1955

Montgomery, Floyd C.; Monthly Weather Review, 83:109, 1955.

The following reports apply to tornadoes seen near Blackwell on May 25, 1955.

One lady who took cover under a stairway ended up one-half block away—— still under the stairway, which was all that was left of her two-story house. She tells me the storm was a black wall and the lightning went up from the ground to the cloud——not from the cloud to the ground.

I stood in the door of my storm cellar and watched the storm go through town. The wind at my place, nine blocks west of the main path, was a dead calm. The storm sounded like a roaring freight train going through open country, only louder. As the funnel was directly east of me, the fire up near the top of the funnel looked like a child's Fourth of July pin wheel. It was something I will not forget for a long time.

GLD-055 ELECTRIC DISCHARGE

GLD-055 [ELECTRICAL ACTIVITY IN VOLCANIC REGION]

Anonymous; Nature, 66:378, August 14, 1902.

> Dr. Hans Reusch, director of the Geological Survey of Norway, has sent us a letter received by him from Dr. W. J. Branch, of Basse-Terre, St. Kitts, one of the Leeward Islands, containing an account of the effects observed there during the recent volcanic eruptions in Martinique and St. Vincent. The volcano Mount Misery, the highest point of the island, exhibited a few indications of sympathy with Mont Pelee and the Soufriere, but no remarkable effects were noticed at the time of the eruptions of these volcanoes. A fortnight after the destruction of St. Pierre, however, a loud explosion was heard by labourers working on the side of Mount Misery; flames seemed to leap out of the ground, and a strong wind swept by, overturning two small houses. At the same time a heavy thunderstorm occurred, with vivid lightning flashes. Though the actions of Mont Pelee and the Soufriere are apparently in sympathy, Dr. Branch's idea is "that Mount Misery is more in league with the volcanoes of Guadeloupe, Montserrat, Dominica and St. Lucia. Their history in the past as well as in the present time seems to me to favour this idea."

The flames issuing from the ground may have the same origin as those sometimes seen during earthquakes.

GLD-056 METEOROLOGICAL PHENOMENON

West, Charles; Nature, 33:245-246, January 14, 1885.

> I shall be obliged if you will allow me to record in your columns the following account of some remarkable phenomena witnessed during a voyage from Sunderland to London, and I trust that if you are good enough to insert this letter, it may be the means of eliciting some explanation from yourself or your readers as to the causes producing such strange effects. Capt. Herring, of the s. s. Fenton, reports to me as follows:-
>
> "We left Sunderland at 3 p. m. on the 7th inst. bound for London, wind west-south-west, with snow squalls and strong sea; towards midnight wind increased, and the squalls cyclonic. When between Flamborough Head and Scarborough, the vessel became enveloped with phosphorescence, the mast-heads exhibiting the curious phenomenon known by sailors as 'Composants' (corpus santi), which in this instance were shaped like a top, about two feet at the widest part, resembling a bunch of mistletoe illuminated. The standing rigging and all protruding objects were in like manner illuminated, and the most extraordinary effect was produced when the mate, who was on the bridge with me at the time, raised his head above the canvas weather-sheeting; the whole of his hair, exposed, and beard were instantly illuminated, and in like manner his hands when elevated became phosphorescent on the outline of his mittens. When under cover of the sheeting there was no appearance of phosphorescence; it would therefore appear that the effect of the wind produced the phenomenon. The weather towards morning moderated, and brilliant flashes of lightning were seen to the eastward. "

GLL-031 LIGHTNING

Goodlet, B. L.; Institute of Electrical Engineers, Journal, 81-1-26, 1937.

A lengthy discussion of the paper by various authors follows the paper proper. Only those portions of the paper relating to the unusual aspects of lightning are quoted below. See GLB-096 for more of this article.

(d) The Localization of Lightning Flashes in Certain Regions. A question often debated is whether or not certain identifiable localities receive an undue proportion of lightning strokes; in other words, does lightning show a preference for certain localities and if so what are the physical features which distinguish such localities? As much nonsense has been talked on this matter it will be discussed in some detail.

Consider a circular area, say, 10 miles in diameter. It is well known that the mean annual number of storms over such an area varies widely according to its position on the globe. Thunderstorms are frequent in the tropics but almost unknown in the polar regions. In a given latitude storms are more frequent on land than at sea, more frequent in mountains than over plains, and exceedingly rare over deserts. The reasons for this variation are also fairly well understood. The absence of storms in the polar regions is due to the dryness of the air and the impossibility of establishing the necessary vertical lapse rate of temperature. For equal insolation air over land becomes hotter than air over water, so that the lapse rate is greater; marsh land, farm land, and forest land all differ in their heat-absorbing power and evaporation rate. In mountain country, convection is assisted by the heating of the slopes (valley breeze) and the upward deflection of warm damp winds. Thunderstorms over deserts are rare because of the lack of moisture for cloud formation. The frequency of thunderstorms over an area is, however, only a rough index of the lightning hazard, since thunderstorms vary greatly in duration and severity. In particular, tropical storms, though frequent and severe, are higher up in the atmosphere (owing to the greater height of the tropopause near the equator) and the proportion of ground strokes seems to be smaller than for storms in temperate regions.

The phrase "localization of lightning flashes" is, however, usually given a more restricted meaning. It is widely believed that there are certain objects and points which are particularly liable to be struck by lightning whenever a storm is overhead. A belief of considerable antiquity, * for which there is much evidence, is that lightning strikes the highest objects in the vicinity. Sir James Frazer attributes the worship of the oak common to most Aryan races of Europe to the fact (?) that the oak is struck by lightning more frequently than any other tree and is therefore favoured by the thunder god. It is a common belief that outcrops of ironstone "attract" the lightning and that the remains of the yule log, if kept throughout the year, will prevent a house being struck. More scientific beliefs at present under discussion are: (i) That lightning "prefers" to strike soil of high conductivity, so that marshes, etc., are especially dangerous, (ii) That chimneys of ionized air which "attract" the lightning exist over certain kinds of ground rich in radioactive substances.

* "Seest thou how God with his lightning smites always the bigger animals and will not suffer them to wax insolent, while those of a lesser bulk chafe him not? How likewise his bolts fall ever on the highest houses and the tallest trees?" (The History of Herodotus, Book 7, chap. 10.)

The evidence in favour of localization of lightning flashes comes mainly from the records of electricity undertakings. Thus Lehmann found that in 9 years a certain 80-km. line received 43 strokes, of which 26 fell on one section 6. 3 km. in length. Investigations showed that this section of the line was traversed by underground springs. It must be remarked that evidence of this kind is not conclusive unless it can be shown that the number and severity of the storms over the particular section are no greater than for the line as a whole. Moreover, electricity undertakings estimate the number of lightning strokes from the number of line flashovers; it is known that many strokes do not cause flashover and that localization of flashovers can be caused by variations in the construction of the line itself. The responsible engineers also differ considerably in their ideas on the reason for such localization. Nevertheless, examination of all available data has left the author with the conviction that the existence of "danger spots," struck more frequently for a given storm exposure, is a fact and not an illusion.

The suggestion that geological factors influence the distribution of lightning strokes appears first in Arago's "Notice Scientifique sur le Tonnerre" (1838). Col. J. T. Bucknill, R. E., in 1881 made the statement "that lightning is most to be feared by those who live on well-conducting areas, even of low elevation, and least to be feared by those who live on non-conducting areas." The modern view is that the danger spots are located where there is a discontinuity in the geological formation. Thus Shipley found danger spots associated with certain outcrops on the Nigerian plateau, while Lehmann found danger spots associated with underground springs. An interesting experiment bearing on this matter has been recently made by Stekolnikov. A metal dish is filled with soil, a small hill is raised above the average level, and a metal ball is buried in the vicinity of this hill. When the dish forms one electrode of an impulse spark-gap, sparks pass to the hill when the soil conductivity is high but to the buried ball when the soil conductivity is low. In the opinion of the author the soil-conductivity hypothesis is well supported.

The air-ionization hypothesis has been the subject of an extensive investigation in France quite recently. A Gerdien air-conductivity meter was mounted on a motor lorry, and measurements of air conductivity were made at a number of points over a large transmission system. The distribution of lightning strokes over this system was then examined for correlation with the distribution of air conductivity. No correlation was found with the total conductivity (i.e. total ion content) of the air, but it was concluded that lightning did tend to fall more frequently at points where the conductivity due to negative ions was greater than the conductivity due to positive ions. The investigators identified high negative-ion conductivity with the presence of a negative space charge and pointed out that on Simpson's theory the lightning channel, being positive, would tend to be drawn to such regions.

The author's criticism of this work is twofold: First, the conductivity measurements were all made during fine weather; it is explicitly stated that during storms violent fluctuations occur and that either positive- or negative-ion conductivity may be in excess. This means that the values of conductivity and conductivity ratio measured in fine weather are no criterion of these quantities in stormy weather. But if air ionization has any influence on the path of the lightning stroke it must surely be the ionization actually existing at the time, not that measured, say, 3 months previously under different conditions. Moreover, ionization at ground level is not the same as ionization in the atmosphere. Secondly, air conductivity is due principally to the small ions of high mobility, whereas space change depends more on the large ions present. A greater negative-ion conductivity is not conclusive proof of a negative space charge. Since

the lightning leader is almost certainly negative, Simpson's theory is beside the point.

What is the real truth on this whole question of the localization of lightning flashes? The author would suggest: First, that there are undoubtedly many localities where the configuration and nature of the ground favours the formation of a storm. Second, that the lightning flash is guided very considerably by the distribution of space charge of opposite sign below the cloud, produced by point discharge. Any object giving a copious point discharge, e. g. a mast or lightning conductor, is therefore particularly liable to be struck. Third, that lightning flashes tend to fall at places where there is a discontinuity of conductivity in the soil, e.g. on faults, outcrops, river banks, underground springs, buried pipes, etc. (pp. 8-9)

(v) Effect of lightning on living creatures. Direct strokes will not be considered here, since it is unlikely that any living creature can survive the close proximity of a 50 000-ampere arc. The less-direct effects are more interesting. The phenomenon known as St. Elmo's fire has already been mentioned. In the intense field at the top of a mountain this discharge is observed from metallic objects carried on the person, although the currents flowing are usually hardly perceptible. These currents are, however, greatly intensified in the vicinity of a lightning leader stroke moving towards the earth. The sudden increase in these point-discharge currents due to a nearby leader stroke is, in the author's opinion, the explanation of many curious shocks received from metal tools and domestic utensils when a flash strikes close by. This effect must not be confused with shocks due to the release of an induced charge on an object due to a flash perhaps half a mile away; induced shocks proceed only from objects of considerable electrostatic capacitance such as an unearthed wireless aerial or a surveyor's chain.

Earth currents can be a source of great danger. If a current of 50 000 amperes enters the soil at a point and spreads out uniformly in all directions the current density, and hence the voltage-drop, along the ground surface will be appreciable even at a considerable distance from the flash. The furrows which sometimes radiate from the point actually struck show that the voltage-drop may be sufficient to produce actual discharges through the soil. The voltage between two points on the earth separated by the length of an animal's stride may therefore be quite sufficient to pass an appreciable current up one leg and down the other. There are many cases of cattle-killing which can be explained in no other manner. When 126 sheep out of a flock of 152 are killed by a single flash it is hardly conceivable that they were all hit by the main channel.

Another danger to cattle arises from wire fences. A wire carried on the top of wooden posts 4 ft. high is fairly well insulated and, if struck, will probably rise to a high voltage for a considerable distance on each side of the stroke. Cattle leaning against such a fence may therefore be killed. In the same way telephone lines can introduce a dangerous voltage into dwellings.

There are several well-authenticated cases of lightning striking a pond or river and killing fishes therein. At first the author was considerably puzzled by this fact since the current which could be passed through a fish in water seemed to be too small to be lethal. Apparently, however, the current required to kill a fish is fairly small, because the large South American electric eel which gives a shock of about 7 amperes at 15 volts kills all fishes within about a yard of itself. Lightning currents are of course much greater than this, even under water, so that perhaps the killing of fishes is not so surprising. It is also possible that the explosion wave radiating in the water from the point struck may have something to do with the matter. It is of course quite easy to produce

luminous discharges in clean water by means of an impulsive voltage, (pp. 9-10)

GLL-032 THE DODGE, NEBRASKA, "FIREBALL"

Jensen, J. C. ; Science, 83:574-575, June 12, 1936.

During the evening of June 24, 1935, famers south of Dodge, Nebraska, reported intense light entering the windows on all sides of their houses. A loud explosive noise followed. The day had been hot,-with a thunderstorm nearby, but no rain fell in the immediate area. A few days later a hole was found in a cornfield. A party, which included two scientists, excavated the hole.

> The dirt was found thrown back from all sides of the 8-inch hole at the center for a distance of about 3 feet and heaped up about 6 inches above the level of the surrounding ground. The hole extended downward 8 feet almost vertically, with an average diameter of 8 inches, then became smaller for the next 7 feet and varied somewhat from the perpendicular. At a depth of 15 feet the diameter had been reduced to about 4 inches and branched out in 3 directions into 2-inch holes, which were followed for 3 or 4 feet into the bank where they disappeared. At this level the clay became very moist, and it was evident that the water level was being approached.
>
> The clay showed signs of fusion at a number of points, and the inside of the hole had a corrugated appearance, as though moist clay had been forced violently back by high pressure. No evidences of any material of different composition than the clay itself were found, and there were no traces either in the hole or outside of it of material which might have been of meteoric origin.

The investigating group concluded that although the eye-witness account suggested a meteorite, the hole was actually caused by lightning. The size and length of the hole, however, were regarded as phenomenal for lightning.

GLL-033 REMARKABLE FORM OF LIGHTNING

Lawrence, E. J. ; Nature, 18:278, July 11, 1878.

> I am able to confirm the fact that lightning occasionally takes the "punctuated" form described by Mr. Joule in Nature, vol. xviii. p. 260. Some forty years ago, in a thunderstorm which I had the good fortune to witness at Ampton, in Suffolk, the lightning (with heavy rain) was almost incessant for half an hour or more, and about a quarter of the flashes (speaking from memory only) presented this unusual appearance. I have often looked out for it since, but only once with success, and then it only showed itself in a single flash out of many. On both occasions the "punctuated" flashes presented in general a curved or sinuous line without sharp angles; and two or three of them in the first-mentioned storm appeared to my eye as closed curves, one an almost perfect figure of 8; but their dazzling brightness made it impossible to speak to this with certainty.

GLM-032 TEKTITES AND THE CRYILLID SHOWER

O'Keefe, John A. ; Sky and Telescope. 21:4-8, January 1961.

O'Keefe was interested primarily in relating the famous 1913 meteor procession to the origin of tektites. Nevertheless, the first portion of the article represents an excellent summary of the work of Chant and Mebane. There were obviously many peculiar aspects to this spectacular event. See GLM-015 for a report on an apparent second sighting of these objects the next day. Other entries dealing with the 1913 procession may be found by consulting the index.

The Cyrillids attracted the attention of astronomers when they passed over Toronto on that night in 1913. According to Prof. C. A. Chant of the University of Toronto: "At about 9:05 on the evening in question there suddenly appeared in the northwestern sky a fiery red body which quickly grew larger as it came nearer, and which was then seen to be followed by a long tail. . . . In the streaming of the tail behind, as well as in the color, both of the head and the tail, it resembled a rocket; but, unlike the rocket, the body showed no indication of dropping to the earth. On the contrary it moved forward on a perfectly horizontal path with peculiar, majestic, dignified deliberation; and continuing in its course, without the least apparent sinking towards the earth, it moved on to the south-west where it simply disappeared in the distance. . . .

"Before the astonishment aroused by this first meteor had subsided, other bodies were seen coming from the north-west, emerging from precisely the same place as the first one. Onward they moved at the same deliberate pace, in twos or threes or fours, with tails streaming behind, though not so long nor so bright as in the first case. They all traversed the same path and were headed for the same point in the south-eastern sky. . . .

"Several report that near the middle of the great procession was a fine large star without a tail, and that a similar body brought up the rear. . . .

"Just as the bodies were vanishing, or shortly afterwards, there was heard in many places a distinct rumbling sound, like distant thunder or like a carriage passing over rough roads or over a bridge. In some cases three such sounds, following at short intervals, were heard; while a number of people felt a shaking of the earth or of the house.

"The entire time occupied by the display cannot be determined accurately, but [was] perhaps 3.3 minutes."

The observations at Toronto were supplemented by others from as far westward in Canada as the vicinity of Regina, Saskatchewan. In the easterly direction, Chant obtained accounts of the same group of bodies from Bermuda. He noticed that the regions from which he had reports lay along an arc of great circle, with observers to the east of the circle seeing the shower in the west, and those west of the circle seeing it in the east. On this basis, Chant put forward the idea that the objects were natural satellites of the earth.

In the following years, new data filled out the arc over which the Cyrillids were seen. First, W. F. Denning discovered some shipboard observations that extended the arc to twice its original length, into the South Atlantic off Cape Sao Roque, Brazil. Next, W. H. Pickering located three more shipboard sightings which filled the gap between New York and Bermuda.

Finally, in the period from 1954 to the present, A. D. Mebane has located several dozen accounts in the files of newspapers in Minnesota, Wisconsin, Michigan, New York, Pennsylvania, and New Jersey. These last are especially welcome because they fill significant gaps in the picture given by Chant, and

assure us that the phenomenon was actually continuous over its whole extent. In particular, they indicate that detonations of the kind heard in Toronto continued at least 200 miles to Towanda, Pennsylvania.

From the observations, it can be shown that the Cryillids were moving about the earth in nearly circular orbits. To see this, imagine instead that they were moving in meteoric paths of low velocity with respect to the earth. Such orbits would be nearly parabolic in the vicinity of our planet. The diagram shows a cross section of the earth in the plane of the great circle along which the Cryillids were seen and a supposed parabolic path. In this case, the orbital perigee would have been at Cape Sao Roque and the bodies would have been traveling parallel to the horizon, as observed there. At Toronto, on the other hand, meteors following such an orbit would fall at an angle of about 30 degrees with respect to the horizon. This flatly contradicts the observations, which, as Chant emphasized, point with remarkable unanimity to horizontal flight in this area.

Further, the fact that the individual meteors were seen for periods of a minute or so indicate that their flight was nearly horizontal. Meteors are generally invisible above heights of 1000 kilometers and below 30 kilometers. If the Cyrillids had been traveling downward at an angle of 30 degrees to the horizontal, their visible paths would have been some 140 kilometers long. Their period of visibility would have been only 12 seconds, at the parabolic velocity of 11.2 kilometers per second, ignoring atmospheric deceleration.

Obviously, the parabolic solutions, with perigee near Cape Sao Roque, will not work. And if we move the perigee north-west along the path, then the meteors would have reached the earth's surface too soon and have been unobservable from Brazil. If we move the perigee farther to the southeast, the angle at Toronto gets even steeper. Increasing the velocity has the same effect, as the orbit becomes hyperbolic. If we lessen the velocity, however, the orbit becomes satellitic. This last is the only possible way to reconcile the orbit with the observations.

From the physical point of view, the narrowness of the belt along which the Cyrillids were seen is hard to understand unless they were following one another in similar orbits. If this was an ordinary meteor shower, the swarm causing it would have to be very thin——about 100 miles across——and some two or three thousand miles long. Furthermore, the swarm would just have happened to strike the earth so that its plane coincided with the center of the planet. Because of the improbability of such' a shower structure, and our preceding arguments, we conclude that the objects of the meteor procession of February 9, 1943, were in face satellites of the earth.

Two attempts have been made to find evidence of a second revolution of the Cyrillids. The map at the right is from examining about 200 United States metropolitan newspapers, principally dailies from about 120 cities——practically the entire collection of the Library of Congress. Two doubtful stories fall off the chart, but on the great circle established by Chant. They were reported in newspapers of February 15th in New York and Philadelphia from the crews of ships docking there. Both give incorrect dates for the shower, and one is obviously inaccurate. Whether these points are included or not, it is clear from the map that accounts of the shower are to be found only along the Chant trace.

Assuming that the Cyrillids were earth satellites, we might expect some of them to make more than one trip around. The next revolution, with a period of 91-1/2 minutes, would have carried them over the Middle West, above the populated regions of Nebraska, Iowa, and Missouri. In the chart above, the

results of a concentrated search along this projected path are compared with the work of Mebane along the Chant trace. Many of these newspapers were examined by me; the rest by reliable investigators recommended by state historical societies. I verified my ability to locate such items by checking newspapers along the Chant trace, even locating a few stories that had been overlooked by the editors with whom Mebane corresponded. But in the area of the expected second passing, none of us was able to locate a single article referring to the shower, with the trivial exception of some reprintings of a wire-service dispatch from Buffalo, New York.

These negative results, many from areas of clear weather on that night, lead to two important conclusions: They reemphasize the idea, first stated by Chant, that the Cyrillids were visible only on and near a great circle; and they make it very unlikely that any substantial part of the Cyrillid shower survived for another circuit of the earth.

GLM-033 LIGHTNING PHENOMENON

Godwin-Austen, W. H.; Nature, 28:173, June 21, 1883.

While watching the incessant play of vivid lightning during the progress of a thunderstorm which was raging close by in the country towards Novara, Arona being just on the northern limit, my wife observed the following curious specta^ cle, the account of which she wrote down immediately afterwards:- At 9. 35 p. m. on Sunday, June 3, a meteor-like object was seen to pass apparently from south to north (window facing due east), coming from the side of the storm and disappearing behind a mass of cloud which capped the high hill of Monte Val Grande above Lago Varese. It was oblately spheroid in form and apparently about the size of a fire-balloon, and with the velocity of a rocket was travelling slowly, for it left no visible track. It was of a bright, clear, whitish yellow, with a bright, pale green colour showing on the northern side when it passed behind the dark cloud. It was about three times as high above the horizon as the low hills opposite Arona, and traversed an angle of 45° horizontally from the point where first seen to its disappearance. The next day (June 4) when visiting friends at the Villa Frauzosine, near Tutra, we ascertained that this meteor-like body had also been seen by two or three persons who were sitting on a terrace watching the brilliant lightning to the south; they observed it moving also from south to north, disappearing behind the mountains to the northward.

GLM-034 [PECULIAR METEORITE AT MARSEILLES]

Anonymous; Nature, 4:454, October 5, 1871.

Les Mondes gives the particulars of a remarkable meteorite observed at Marseilles by M. Coggia, on the 1st of August. It made its appearance at lOh. 43m., Marseilles mean time, at a point situated near the centre of the triangle formed by § Serpentis and & and *u* Ophiuchi. The course was remarkably slow, in an easterly direction; at lOh. 45m. 30s. it passed between and \x<i Sagittarii, and at lOh. 46m. 35s. it almost occulted Saturn. The course be-

came then still slower; at lOh. 49m. 50s. it passed a little below *r* Sagittarii, and at lOh. 50m. 40s. south of the star *f* of the same constellation. At lOh. 52m. 30s. it passed between *i* and *B* Capricorni, where it remained for a moment stationary, then changing its course, it took a northerly direction, leaving at lOh. 57m. 50s. the star V Aquarii 1° 30' to the west and again stopping, at lOh. 59m. 30s., a little south-west of £ Aquarii. Regaining its original easterly direction, it then passed *0* Aquarii, stopping again near Aquarii, and then fell rapidly in a perpendicular direction near *S* Capricorni, and leaving to the east the almost full moon. It finally disappeared a little north of *0* Pise, austral, at llh. 3m. 28s. The diameter, which was at first about 15\ diminished rapidly, was a little over 4' when it approached Saturn, and finally had scarcely more than the apparent size of Venus. During its perpendicular fall to the horizon, it gave out vivid scintillations.

It is the "meteorite's" change of course that makes the observation worthwhile recording here. See also the following two items.

GLM-035 EXTRAORDINARY METEOR SEEN AT MARSEILLES

Coggia, Dr.; Chemical News, 24:193, October 20, 1871.

Dr. Coggia.——On August 1 last, at 10.43 p.m. Marseilles meantime (5° 22' 19" E. of London), the author observed a large blood-red coloured meteorite, which moved slowly in a direction first west and next north, having been lost sight of at 11° 3' 28" p. m. The diameter (apparent) was about 15' at first, but decreased to 0. 4'. Before being lost sight of, this meteorite appeared to emit incandescent sparks.

GLM-036 THE MARSEILLES METEORITE

Herschel, A. S.; Nature, 4:503-504, October 26, 1871.

It will probably occur to most of your readers, as it immediately suggested itself to me, on reading in your journal of the 5th inst. a description from Les Mondes of a remarkable meteorite observed at Marseilles by M. Coggia, on the 1st of August last, that the bright object having an apparent diameter, at first of about 15', and at last of a little over 4', whose uncertain course was noted for eighteen minutes by the stars, was really nothing more extraordinary than a fire-balloon; or it may, possibly, have been some description of brighter signal-light. The planet Saturn, and the other stars named in the description, were all at the low altitude above the horizon, at which a fire-balloon, and other bright signal-lights of ordinary size, floating at an ordinary height in the air, would have about the apparent diameter of the "meteorite." Its apparent diminution in size was, also, perhaps, either the effect of its increasing distance or of its gradually fading light. After alternately remaining stationary, and changing its apparent course two or three times, it at last fell rapidly in a perpendicular direction. The burning tow, or other inflamed substance with which it was inflated, appears to have detached itself from, or, it may be, to have set fire to the balloon, since it was remarked that during its perpendicular fall to the horizon it gave out vivid scintillations.

See the preceding two entries for further discussion.

GLN-029 IGNIS FATUUS

Gillmor, Daniel S., ed.; Scientific Study of Unidentified Flying Objects, Bantam Books, Inc., New York, 1969.

In swamps and marshes, methane, *CHA* (and also phosphine PH_3), is released by decaying organic matter. When the methane ignites, either by spontaneous combustion or by electrical discharges produced during times of thunderstorm activity, luminous globes which float above the swamp can be seen. These are not plasma effects, but resemble them in appearance. They are called Ignis Fatuus (foolish fire), jack-o-lanterns, will-o-the-wisp, or simply swamp (or marsh) gas. The colors are reported to be yellow, sometimes red or blue. Thunderstorms and other electrical activity around swamps seem to stimulate this effect.

Occasionally observers have placed their hands into these luminescent gases without feeling any heat. Dry reeds did not catch fire. Copper rods did not heat up. Occasionally however paper was ignited, (p. 736) (Martin D. Altschuler)

A swamp is a place of rotting vegetation and decomposition. Swamps are not a province of astronomers. Yet, the famous Dutch astronomer, Minnaert, in his book, "Light and Colour in the Open Air," describes lights that have been seen in swamps by the astronomer, Bessel, and other excellent observers. The lights resemble tiny flames sometimes seen right on the ground and sometimes rising and floating above it. The flames go out in one place and suddenly appear in another, giving the illusion of motion. The colors are sometimes yellow, sometimes red, and sometimes blue-green. No heat is felt, and the lights do not burn or char the ground. They can appear for hours at a stretch and sometimes for a whole night. Generally, there is no smell and no sound except for the popping sound of little explosions such as when a gas burner ignites.

The rotting vegetation produces marsh gas which can be trapped during the winter by ice. When the spring thaw occurs, the gas may be released in some quantity. The flame, Minnaert says, is a form of chemical luminescence, and its low temperature is one of its peculiar features. Exactly how it occurs is not known and could well be the subject of further investigation, (p. 540) (E. U. Condon)

GLN-030 THE LIGHTS OF SUMMERVILLE

Fuller, Curtis; Fate, 15:16-17, July 1962

Since we have mentioned fireballs we feel constrained to tell you about the strange lights that have intrigued the residents of Summerville, S. C., since last December.

The Charlotte, N. C. News reported in mid-March that the light was discovered by young persons on a date on Sheep Island Road, which is built over an old railroad right-of-way through swampy land near Summerville.

The light changes color and shape as it scoots up and down the road, sometimes high, sometimes, low. It has been chased by automobiles at speeds up to 60 m.p.h. but never has been caught.

One young man said he saw the light sitting on the hood of his car. Another heard the faint tinkling of a bell. When the light appeared the bell began to ring like mad.

GLN-031 NOCTURNAL LIGHTS

GLN-031 LUMINOUS APPEARANCE IN THE ATMOSPHERE

Webster, N. ; American Journal of Science, 1:12:380, 1827.

In Vol. xi, No. 2, of the Journal of Science and Arts, Mr. C. Atwater has communicated an account of a spot or spots, near the horizon, appearing as if lighted, and giving rise to a belief that there was a great fire in that direction. He remarks that he has often noticed these light spots in Ohio, but not on the east of the Alleghanies.

I would only remark that I have observed similar phenomena in New England. I recollect one instance, when I resided at Amherst, in Hampshire County, Mass. a bright light in the North East, near the horizon, appeared as the light of a building on fire appears at night at the distance of several miles. I expected, in that instance, every hour to hear that some building in Shutesbury or New Salem, had been burnt; and so strong was my belief of it, that I repeatedly asked my neighbors whether they had heard of any such event. At last I met a gentleman who had just come from one of those towns, who told me he had heard of no fire in that quarter, which convinced me that the phenomenon was merely atmospheric.

GLN-032 STRANGE LIGHTS IN WALES

R., A. ; Notes and Queries, 5:3:306, April 17, 1875

A gentleman writes from Pwllheli, a coast town in Carnarvonshire, to the Field newspaper of Feb. 20, as follows:-

"Some few days ago we witnessed here what we have never seen before—— certain lights, eight in number, extending over, I should say, a distance of 8 miles; all seemed to keep their own ground, although moving in horizontal, perpendicular, and zig-zag directions. Sometimes they were of a light blue colour, then like the bright light of a carriage lamp, then almost like an electric light, and going out altogether, in a few minutes would appear again dimly, and come up as before. One of my keepers, who is nearly 70 years of age, has not, nor has any one else in this vicinity, seen the same before. Can any of your numerous readers inform me whether they are will-o'-the-wisps, or what? We have seen three at a time afterwards on four or five occasions. "

Surely we are not going to have a repetition of the "Fiery Exhalation" mentioned by Evelyn in his Diary, 22nd April, 1694, and fully discussed in Gibson's continuation of Camden. These "Mephitic Vapours, " as they were called, occurred on the same coast.

These strange lights should be related to those seen during the 1905 religious revival, as described in GLN-002.

GLW-007 REPORT OF AN UNUSUAL PHENOMENON AT SEA

Pringle, Edward H. ; Nature, 20:402-403, August 21, 1879.

As the unusual phenomena observed in the Persian Gulf, described in Nature, vol. xx. p. 291, [GLW-005] has hitherto called forth no remarks, I venture to put forward a suggestion that may be of service in elucidating the matter.

First, I would observe that the so-called parallel waves were probably arcs of large concentric circles, whose common centre lay south-south-west of H. M. S. Vulture's first, and east of her last, position. The distance between these positions was about a knot and a half, therefore the vessel was never nearer this centre than about half a mile, and a short arc of a circle of this radius might well be deemed straight.

The accompanying diagram, drawn from the data, shows the position of the centre of disturbance, and of the luminous waves, with relation to the course of the ship, taking the above view, which I think is borne out by the character of the second series of luminous waves through which H. M. S. Vulture passed.

Most living creatures possessing phosphorescence have more or less control over its display. In the case of the fire-fly, the light that one emits calls forth almost instantaneously answering flashes from others. No dweller in the tropics can have failed to observe the manner in which trees are lit up by the simultaneous flash of thousands of fire-flies, and the period of darkness that intervenes before the next flash. If then we consider the Vulture to have passed through a shoal (if I may so term it) of animalculae, possessing the power of exhibiting phosphorescence intermittently, and exciting each other to do so, the impulse travelling from one to another at the rate of 125 feet a second, and the

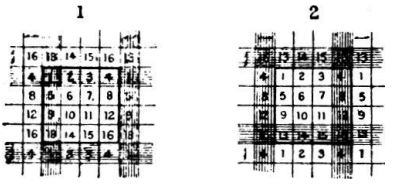


Diagram showing intersections of luminous waves from GLW-007. Scale: 1 inch = 50 feet.

display of light to the dark interval bearing the ratio 1 to 3 (in time, 1/5 of a second to 3/5), we have accounted for the phenomena so far as the luminous waves are concerned.

What were the central disturbances that originated the action, it is impossible to say, though it is easy to imagine several causes of irritation, that would not have been detected by the simple observations taken on board the vessel.

The luminous waves of the smaller series "meeting the parallel waves from south-east did not cross, but appeared to obliterate each other at the moving point of contact." The above is difficult to explain, if the luminosity of the waves was obliterated at the actual intersections. It can however be readily shown that close to the intersections are spaces where the phosphorescence of the animalculae would have to be displayed for twice as long a period as in other positions, and we have but to admit a want of energy to meet this call, and dark spaces will appear in each system of waves, immediately following the passage of the crossing wave.

This would certainly give the appearance of one wave obliterating the other.

A second diagram explains this simply. Here a portion of ocean is divided into numbered squares of 25 feet, and the advance of the 25' luminous waves, 75' apart is shown in two following positions. It will be seen that spaces numbered 4 and 13 fall successively under the impulses. Similarly, in the next 25' advance of the waves, would all those numbered 12 and 15, and so on, the assumed dark spaces following in the wake of each intersection, as it pursues its diagonal course.

GLW-008 REPORT OF AN UNUSUAL PHENOMENON OBSERVED AT SEA

Moss, Edward L.; Nature, 20:428, August 28, 1879.

I can supply a second instance of the "unusual phenomenon observed at sea," communicated by the Hydrographer of the Navy to Nature, vol. xxi, p. 291. [GLW-005]

One night in April, 1875 (I cannot give the exact date, as my notes were lost in the ship) H. M. S. Bulldog was lying becalmed in a glassy sea off a point of land a few miles north of Vera Cruz, when a line of light appeared along the northern horizon, and unaccompanied by the least breath of wind, swept towards and past the ship, in a series of swift luminous pulsations, precisely similar to those described by Mr. Pringle. Acting on the old sea formula, "observed a phenomenon, caught a bucketful," we dipped up some of the water, and found noctilucae and crustaceans in it. These may have supplied the luminosity, but if so, the exceedingly swift-travelling cause of their stimulation would still remain unaccounted for.

A squall accompanied by incessant thunder and lightning overtook the ship the same night.

GLW-009 [MORE WHEELS OF LIGHT]

Anonymous; Nature, 86:90, March 16, 1911.

The meteorological chart of the Indian Ocean for March, issued by the Meteorological Committee, quotes several cases of phosphorescent seas that

have been observed in recent years. Among the most interesting is one forwarded to the Danish Meteorological Institute by Captain Gabe in the Strait of Malacca in June, 1909. Luminous waves were observed travelling from west to east, and gradually assumed the form of long arms, with dark intervals between them. These issued from an apparent focus, around which they rotated, which seemed to be on the horizon. An illustration of the phenomenon shows that the beams of light were somewhat curved, the concave edge being in the direction of rotation (clockwise). The brightness lasted about a quarter of an hour. A somewhat similar case of rotatory light system was observed by Captain Breyer in August last near the Natuna Islands, but the direction of rotation round the apparent focus in this instance was anti-clockwise.

GLW-010 PHOSPHORESCENCE ON A SCOTTISH LOCH

Jamieson, Thos.; Nature, 79:309, January 14, 1909.

There may be some connection between the following phenomenon and the "white seas" and "wheels of light."

A remarkable illumination was observed about eight years ago on a certain part of Loch Bulig (which lies in the north-western boundary of Aberdeenshire). As it appears to be the only known occurrence of phosphorescence on a Scottish loch, your readers may be interested in it. It appeared in the form of innumerable brilliant lights, snooting rapidly on the surface of the water, but many leaping one or two feet above it- It lasted for about a minute, and was repeated twice at intervals of about ten minutes. The effect was very striking, the brilliance being almost dazzling. It seemed that it could not be accounted for in any other way than by phosphorescent animalculae, disturbed probably by a shoal of fish which are known to inhabit the loch.

Inquiry elicited the information that near where the lights were seen a soft bank stretched out from the side towards the centre of the loch. I have been desirous since that time to gather some of the deposit, if possible, for examination, but only a few months ago was I able to carry out my intention. I found it was a matter of no little difficulty, as the loch at that part is about 25 feet deep, and though it is usually quite smooth it sometimes is somewhat rough. The first attempt was a failure, the day being squally, the waves 2 or 3 feet high, and the strong wind and current rendered it difficult to locate the bank and collect specimens. The second attempt, however, was successful, and I found that the bottom was generally stony, but gave place to soft material just above where the lights had been seen. I collected two quantities of the deposit, and found that it consisted of sand mixed with a large quantity of carbonaceous matter, mostly in the form of small rolls, half an inch to one inch long. Microscopic examination showed that these rolls contained animals encased like tubicolous annelids; they were quite active, emerging from the tube, grasping black particles, and then retreating; some were encased in parchment-like tubes, through which the rapid actions of the animal could be distinctly seen; one was found with a transparent tunic, hanging by a ring from the neck, resembling _OxyeJlnrj¸£OS^alis_ (Hydrophilideae); I still have this specimen. Along with these and other animals were numerous diatoms, nematodes, &c. As some of these animals belong to classes which are known to be phosphorescent, it seems that their presence in the deposit is sufficient to account for the remarkable appearance seen. This was confirmed by finding that the sand con-

tained much more phosphate than sand usually contains; also, by testing with ammonium molybdate some of the black matter, including one of the black rolls containing an animal, after a few hours a distinct yellow precipitate was found, but only in the vicinity of the black roll.

I should think that this deposit would form an interesting preserve for zoologists, and therefore I relate the circumstance, and shall be glad to give any further information to anyone who may desire it.

GLW-011 A WHITE, OR MILKY SEA

Pidgeon, Dan; Nature, 58:520-521, September 29, 1898.

I left Bombay for England in January 1881, on board the P. and O. s. s. Sumatra (Captain Briscoe), and on February 1, the vessel being then in N. lat. 14" and E. long. 53° (not far from the position described by your correspondent) had an opportunity of witnessing the phenomenon known as the "Milky Sea," rarely seen except in these waters. The following extract from my book, "An Engineer's Holiday," describing and explaining the appearance, may interest Mr. Barrett:-

"The whole ocean, from the ship to the visible horizon, looked as if it were covered with snow, whose surface evidently shone by the reflected light of the sky, for Venus, being very bright, threw a distinguishable line of radiance across it, while the phosphorescent crests of waves were now and then seen breaking above the layer of shining matter which overlaid the water.

"A current, always encountered north of Socotra, set the ship, on the day in question, fourteen miles to the northward of her course. This stream was crowded with large meduse, visible not only during the day, but also at night, when, being themselves non-luminous, they appeared as whirling black discs in the general phosphorescence of the ship's wake. The ship's officers fully believed that this current brings with it, besides jelly fish, enormous quantities of decayed and phosphorescent matter to whose presence they attributed the appearance of the 'Milky Sea.'

"The fact, however, that the seeming snow reflects light, and is broken through by quite small waves, disposes of this explanation, and we soon convinced ourselves that the phenomenon is really due to a thin layer of mist lying on the water, exactly resembling one of those local fogs which every one has seen, and which may give to a valley or even a slight depression the appearance of being snowed up. It occurs when the sea is colder than the atmosphere, and the latter still and heavily loaded with aqueous vapour. Under these circumstances, a layer of air immediately in contact with the water is chilled below the dew point and becomes misty, while that above remains transparent: the upper surface of such a fog, which is only a few inches thick, being seen by the reflected light of the sky" ("An Engineer's Holiday," vol. ii, p. 314).

The temperature of the sea on the night in question was 70°F., while that of the air was 79°, an unusual amount of difference in the Arabian sea. Water, brought on deck by a bucket, showed no signs of milkiness, though crowded as usual with various phosphorescent organisms.

SECTION GM:
MAGNETIC AND ELECTRICAL PHENOMENA

The "strange phenomena reported here are observed mainly with instruments; the observers, consequently, are usually scientists. A few exceptions exist where individuals have felt electric shocks.

The perturbations and anomalies of magnetic and electrical fields, such as those apparently caused by meteorites, may lead to unexpected insights regarding the interactions between seemingly unrelated geophysical phenomena.

*GMA	Atmospheric electricity. Flow of charge through the atmosphere as related to thunderstorms, auroras, earthquakes and similar events.
*GME	Earth currents. Flow of charge in the earth's crust due to sundry geophysical phenomena.
*GMG	Magnetic anomalies. Unexpected variations of the terrestrial magnetic field in time and space.
GMM	Magnetic and electrical perturbations apparently caused by meteorites.
GMS	Solar, lunar, and planetary correlations.

•This subsection not represented in Volume G2.

GMM-001 OBSERVED MAGNETIC EFFECTS FROM METEORS

Jenkins, Alvin W., et al; Journal of Geophysical Research, 65:1617-1619, May 1960. (Copyright by the American Geophysical Union)

A correlation between geomagnetic fluctuations and meteoric activity was reported by Kalashnikov, who used sensitive fluxmeters and a photographic recording technique. In his work, he noted an increase in the number of pulses in the vertical component over the dates of meteor showers. Hawkins, using more sensitive equipment also sensitive to the vertical component, attempted to correlate pulses with visual meteors. His results were negative, indicating only such correlation as might be expected statistically. A real discrepancy thus exists between the results of these two workers. Hawkins has pointed out, however, that Kalashnikov's results may not be significant, since the correlation he noted is not much greater than that expected to occur accidentally. A preliminary analysis of data recently available from the IGY program concerned with subaudio fluctuations in the geomagnetic field seems to indicate that meteoric activity and the average level of the fluctuations are related.

The subaudio program is a study of geomagnetic fluctuations in the 1- to 50-cps range. Three mutually perpendicular coils are used to detect variations in the magnetic field. The resulting electrical signals are amplified and recorded on magnetic tape. The tape is later played back through filters which analyze each signal into six approximately octave frequency bands. The filtered signals are rectified and integrated for the 15 minutes of recording time provided each hour, resulting in a single number indicative of the average level of the geomagnetic fluctuations for each frequency band for each hour. The program has been active for more than a year, with five recording stations gathering data. Only recently, however, has the reduction equipment been put into operation, so that only a small fraction of the data so far appears in reduced form.

A striking feature of the activity levels thus far available is the occurrence of occasional large increases in the frequency band centered at 1.5 cps. In particular, the data from the Denver, Colorado, recording station show an increase in this band of about 5 or 6 times the usual level on the night of December 12-13, 1959. Since this is also approximately the expected time of the maximum of the Geminid meteor shower, a connection between the two events was suggested.

The article concludes with data and graphs which tend to support a connection between meteors and geomagnetic fluctuations.

GMM-002 [ELECTRIC EFFECTS OF METEORITES]

Gillmor, Daniel S.; Scientific Study of Unidentified Flying Objects, Bantam Books, New York, 1969.

During the fall of one of the largest bolides, near Sikhote-Alin, near Vladivostok (USSR), an electrician on a telephone pole received a strong electric shock from disconnected wires at the instant the bolide became visible. The shock may have been due to other cuases, but the possibility of strong electromagnetic effects is not ruled out. (p. 745) (Martin D. Altschuler)

GMM-003 METEORITE EFFECTS

Meteors are known to leave ionized trails, but it does not seem reasonable that electric induction effects could be transmitted over such distances. Earthquakes, ball lightning, etc. have produced similar effects.

GMM-003 MAGNETIC MICROPULSATIONS ACCOMPANYING METEOR ACTIVITY

Campbell, Wallace H.; Journal of Geophysical Research, 65:2241-2245, August 1960.

Only the abstract and experimental procedure are reproduced below.

Abstract. **Increased activity of magnetic micropulsations with periods of 5 to 30 seconds and magnetic flux densities of 20 to 320 m was found to accompany the ^ Aquarid, $ Aquarid, and Perseid meteor showers in 1958. Conflicting reports are discussed.**

Procedure. **Magnetic field oscillations were measured continuously from March through September 1958 at a California desert site, 33°21.5*N, 116° 17'W. The detection system had a north-axis loop antenna with 21,586 turns of 2-meter diameter and a band pass with 3-db points at 0.04 and 0.4 c/s. The limiting sensitivity was 20 mjf. Of 4808 hours sampled, 60 per cent had micropulsations with periods of 5 to 30 seconds.**

GMM-004 AN ANALYSIS OF THE MAGNETIC EFFECT FROM METEOR SHOWERS

Green, Richard G.; Journal of Geophysical Research, 72:2309-2313, May 1, 1967.

Abstract. **Magnetic effects due to the passage of the Geminid meteors through the ionosphere were computed using an equation derived by Chapman and Ashour. The observed micropulsation activity at Jicamarca, Peru, and Kingston, Rhode Island, was compared with the predicted value. No striking similarity was found either in magnitude or phase. An amplitude comparison shows an observed result 150 times greater than predicted for Jicamarca and five times greater than predicted for Kingston. The best comparison of predictions with data was restricted to a phase maxima at 2300 and 0530 LT.**

GMS-001 INFLUENCE OF MOON ON MAGNETIC NEEDLE

Bache, A.D.; American Journal of Science, 81:98-103, 1861, and 84:381-387, 1862.

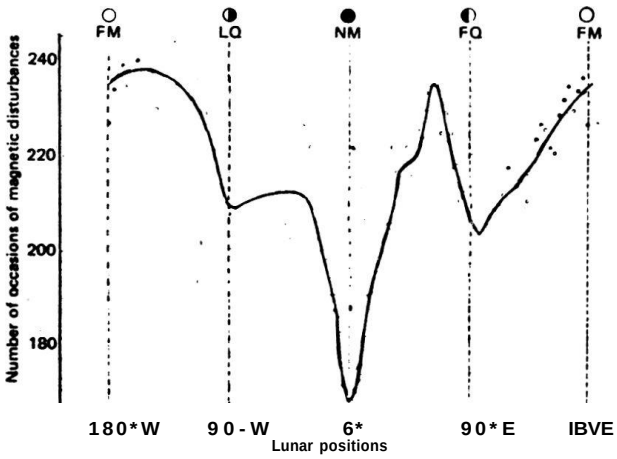
Compiler's Summary: The reported effects are small, barely beyond the probable error.

GMS-002 THE INFLUENCE OF THE MOON ON GEOMAGNETIC DISTURBANCES

Bigg, E. K.; Journal of Geophysical Research, 68:1409-1413, March 1, 1963.

Abstract. It is shown that occurrences of geomagnetic disturbances of various intensities are not uniformly distributed in lunar phase. There is a tendency for storms to occur preferentially near first and third quarters and to avoid dates corresponding to new moon.

The position of the moon has also been correlated with the rate of incoming meteors and with rainfall. See Subsections GMS and GWS.



The distribution in lunar phase of magnetic disturbances. (Figure 4 from GMS-002)

GMS-003 SOLAR, LUNAR, AND PLANETARY EFFECTS

GMS-003 CONCERNING LUNAR MODULATION OF GEOMAGNETIC ACTIVITY

Bell, B., and Defouw, R. J.; Journal of Geophysical Research, 69:3169-3174, August 1, 1964.

Abstract. The behavior of the daily K_p index of magnetic activity is investigated as a function of lunar phase by the method of superposed epochs. The analysis indicates a slight but statistically significant enhancement of geomagnetic disturbance during several days following full moon and, with marginal significance, a slight diminution of disturbance during several days preceding full moon. A small dip in K_p, found at the phase of new moon, is shown to be without statistical significance.

GMS-004 A SUPPOSED DEPENDENCE OF GEOMAGNETIC STORMINESS ON LUNAR PHASE

Davidson, T. W., and Martyn, D. F.; Journal of Geophysical Research, 69:3973-3979, October 1, 1964. (Copyright by the American Geophysical Union)

Abstract. The geomagnetic daily planetary indices from 1932 to 1961, and also the starting days of great magnetic storms from 1840 to 1954, are examined for possible dependence on lunar phase. It is concluded, in agreement with Bartels but contrary to the findings of Bigg, that there is no evidence of any such dependence.

Conclusion. It is concluded, in agreement with Bartels, that there is no significant variation with lunar phase of either (a) the daily geomagnetic planetary index, or of (b) the time of commencement of major magnetic storms. In view of these findings it would appear profitless to examine the possible dependence of Greenwich 'small' storms on lunar phase, since they exert a strong influence on the A_p indices. It would appear highly desirable that authors seeking to establish the existence of periodicites in geophysical phenomena should carefully examine the statistical significance of their conclusions: sound methods of assessing this were clearly laid down by Bartels three decades ago and have been used with success'by Chapman and others in the ensuing years.

GMS-005 A SEARCH FOR CORRELATION BETWEEN K_p AND THE LUNAR PHASE

Michel, F. C., et al; Journal of Geophysical Research, 69:4177-4181, October 1, 1964.

One of the first scientific activities seems to date from prehistory, namely, the search for correlation between the motion of heavenly bodies and almost any other observable phenomenon, ranging from political events to biological functions. This active field of endeavor has continued up to the present. This note differs somewhat, perhaps, from the genre in being an account of an unsuccessful search; we report it here in the hopes of diverting attention and effort into more productive channels in accord with Bartels' recent analysis.

The first paragraph quoted above insinuates that scientists searching for lunar effects on geophysical phenomena are akin to astrologers, supposing this to be insulting. In any event the unsurprising conclusion of this paper is that no correlation exists between the lunar phase and the geomagnetic parameter K_p.

GMS-006 LUNAR INFLUENCES ON THE FREQUENCY OF MAGNETIC STORMS

Bigg, E. K.; Journal of Geophysical Research, 69:4971-4974, December 1, 1964

Bigg has been criticized for his attempts to find correlations between geophysical phenomena and the positions of the moon and planets. In this paper he replies to attacks on his statistics. Only his conclusions are quoted.

Conclusions. I have attempted in this discussion to make it clear that an adequate statistical examination of the reality of lunar effects on magnetic storms is not as straightforward as critics have claimed. The desirability of a good statistical treatment is obvious, but it must be less superficial than those so far attempted. The minimum requirements of a test are that it should:

1. Examine all aspects of the supposed modulation.
2. Give an upper limit to the magnitude of the supposed effect if it fails to detect it.
3. Contain only justifiable assumptions about the randomness of the data.

It also seems reasonable to consider the evidence from all relevant sets of data taken together, in addition to dissecting them individually.

Further examination of the reality of the moon's influence can then proceed in two ways. One is to compare effects in independent data which should be subject to the same influences——a procedure which requires that a particular hypothesis should be adopted. The other is to search for anomalies in magnetic field or electron concentration measurements from space probes or artificial satellites, which can be associated with the position of planets or the moon. The final answer on the reality of the influences will come from these measurements rather than from statistics.

GMS-007 VARIATIONS OF GEOMAGNETIC ACTIVITY WITH LUNAR PHASE

Stolov, Harold L., and Cameron, A. G. W.; Journal of Geophysical Research, 69:4975-4982, December 1, 1964.

Abstract. An analysis of 31 years of Kp data suggests a variation of geomagnetic disturbance with lunar phase. A general increase in geomagnetic activity of about 4% begins after full moon and lasts for seven days. A general decrease in geomagnetic activity of about 4% is found for the seven days preceding full moon. A study of randomized data indicates that the probability that these variations should have occurred by chance is less than 5%. The effect is found to be associated with the Kp data derived from periods of geomagnetic quiet conditions; it is not evident in the data from disturbed periods.

GMS-008 SOLAR, LUNAR, AND PLANETARY EFFECTS

GMS-008 PLANETARY EFFECTS ON MAGNETIC ACTIVITY

Atkinson, Gerald; American Geophysical Union, Transactions, 45:630-631, December 1964.

Statistical evidence indicates that the positions of the Moon, Mercury, and Venus affect magnetic activity frequency observed at the Earth, and the position of the Earth affects the frequency of blue clearings on Mars. This study shows that these effects may be explained as a result of the action of shock and bow waves formed by these bodies in the supersonically streaming interplanetary plasma. The attenuation of large kinetic energy variations in the streaming plasma behind such bodies is shown to be equal to the square of the ratio of the Mach number upstream to the Mach number downstream. For typical solar induced activity, this implies an attenuation coefficient of approximately 1/2-1/3, It is also shown that an activity increase is expected in the bow wave. The observational data fit a model with bow waves of Mach numbers 2. 5 and 15 corresponding to the two waves predicted by the theory. The Moon's effect varies from that of the planets in a manner that can be explained by its closeness to the magnetosphere.

Studies like that above show a surprisingly tight-knit solar system with many hitherto unsuspecting interacting effects. See also data on the effect of planetary positions upon short-wave propagation. (Subsection GET)

GMS-009 EVIDENCE OF A SOLAR INFLUENCE ON THE ATMOSPHERIC ELECTRIC ELEMENTS AT MAUNA LOA OBSERVATORY

Cobb, William E. ; Monthly Weather Review, 95:905-911, 1967.

This paper provides evidence of the effects of solar activity on atmospheric electricity. Although the focus is on thunderstorms, it is possible that the same forces may affect such phenomena as the Andes Glow, aurora-like activity, wheels of light, etc. Only the pertinent (i.e., "strange") portions are quoted.

5. Studies of Other Investigators

The solar-terrestrial relationship found at Mauna Loa has been found by others. One of the earliest investigations was that of Bauer who collected potential gradient records in Europe for the years 1886 to 1923 and found that the electric field increased during periods of increased "sun-spottedness. "

Much more recently, Reiter made atmospheric electric measurements from several mountain sites in central Europe and reported a peak increase of about 5 percent for both the electric field and the air-earth current, usually occurring about 4 days after a solar flare. Reiter's measurements from 1956-1960 were made during the more active years of the 11-yr. solar cycle. It is significant that the monitored atmospheric electric climate at two widely separated mountain tops in Germany and Hawaii have both revealed the same solar-terrestrial correlation.

6. Global Thunderstorm Activity and the Air-Earth Conduction Current

Investigations of the earth-ionosphere electric circuit ultimately involve as the controlling parameter the global thunderstorm activity. As stated earlier,

the current flow within the earth-ionosphere electrical circuit is, according to the classical concept, controlled and maintained by the global thunderstorm activity.

Through the years there have been several reports relating thunderstorm frequency and solar activity. Septer, Brooks, Flohn, and Reiter have all found essentially the same correlation, that is, an increase in thunderstorm frequency during increased solar activity. More recently, Sartor, (in this issue), has found evidence relating the occurrence of sporadic *E* with heavy thunderstorm precipitation.

The investigations above, concerning increased thunderstorm activity and the solar flare-atmospheric electric relationship found at Mauna Loa and in Europe by Reiter, represent considerable evidence that both the earth ionosphere conduction current and the global thunderstorm activity are increased by corpusular solar radiation penetrating the earth's atmosphere.

The air-earth conduction current is governed by the basic Ohm's law relationship, $j=EA$, where j is the air-earth current, E is the electric field, and X is the conductivity. As explained in section 3, it is this thunderstorm generated "supply current" which maintains the charge balance on the positively charged equivalent potential layer and the negatively charged earth. What influence an increase in the basic current flow has on the thunderstorm activity is not known. It would be surprising, however, if an increase of 75 percent in the air-earth current, such as occurred during a 6-hr. period in July 1961, did not affect the thunderstorm activity either as a result of an increased efficiency of the individual storms or as an increase in the total number of storms. Any increase in the upward directed positive current beneath and above a thunderstorm would seem likely to enhance those interior thunderstorm electrical processes inherent in the separation of charge and the formation of rain.

The evidence presented in this report strongly suggests that corpuscular solar radiation exhibits a small but significant external influence on the earth-ionosphere electric circuit which is otherwise controlled and maintained by the global thunderstorm activity. The measured increase in the fair-weather air-earth current following solar flares must necessarily be accompanied by an increase in the return flow of positive charge to the equivalent potential layer and this return current will for the most part take place in regions of thunderstorm activity.

It has been estimated that as many as 3, 600 thunderstorms are continually in existence. Quite likely, there are as many potential storms which approach but never reach the thunderstorm stage. The global thunderstorm activity has never been adequately measured. Hopefully, satellite detection of spherics will soon provide a continuous measurement of this most important atmospheric electric parameter and help in explaining the solar-terrestrial phenomenon discussed here.

7. Summary

The monitored atmospheric electric elements at Mauna Loa Observatory have provided good evidence of a direct solar influence on some of the electric elements recorded at the mountain Observatory. In the majority of occurrences, both the atmospheric electric field and the air-earth conduction current were increased above their mean values following solar flares. At present, there is not satisfactory explanation of the phenomenon. The answers lie in a better understanding of the effect of solar corpuscular radiation on the earth-ionosphere electric circuit.

The evidence found at Mauna Loa in Hawaii and at Zugspitze in Germany suggests that atmospheric electric measurements made from isolated moun-

tain sites are more likely to respond to solar effects and changes within the earth-ionosphere spherical condenser. Because these mountains extend well into the more highly conducting atmosphere, the transfer of charge between the ionosphere and the mountain tops takes place with greater ease than from ionosphere to sea level.

It is important that such measurements be continued through both "quiet" and "disturbed" solar cycles.

GMS-010 THE LUNAR INFLUENCE ON RADIO-AURORA

Forsyth, P. A. ; Journal of Atmospheric and Terrestrial Physics, 32:251-255, February 1970.

Compiler's Summary: Forsyth notes that a 29. 5-day periodicity does exist for radio-aurora but that it seems to be a chance interaction of other well-known periodicities.

GMS-011 GRAVITY WAVES: CORRELATION WITH GEOMAGNETIC STORMS

Metz, William D.; Science, 180:1161-1162, June 15, 1973.

Metz, a staff writer for Science, summarizes current research relative to the purported detection of gravitational waves. The first report of gravitational radiation was made in 1969 by Joseph Weber, who had constructed a special detector at the University of Maryland. In 1972, however, Russian scientists noted that Weber's events were correlated with geomagnetic disturbances. Metz then goes on to describe a recent experiment.

> Last month J. A. Tyson, C. G. Maclennan, and L. J. Lanzerotti at the Bell Laboratories, Murray Hill, New Jersey, evaluated the correlation of a much larger sample of Weber's data with various geophysical, meteorological, and other phenomena (2). The sample they analyzed consisted of 262 gravitational radiation events observed over a 4-month period ending 22 December 1969, and is much larger than any sample of raw data Weber and his colleagues have published.
>
> The geomagnetic correlation did not disappear when more data were studied. The Scientists at Bell Laboratories found a relatively high correlation, at 2. 7 standard deviations, with the geomagnetic index, that measures changes in the ring currents circling the earth in the magnetosphere, and a lower correlation, at 2 standard deviations, with the geomagnetic activity index at Fredericksburg, Virginia. Correlations at 2 standard deviations were also found with sunspots and earthquakes.

Metz goes on to note that Weber's equipment contains almost no magnetic material and would seem to be a poor detector of magnetic variations. Finally, it is pointed out that to date other researchers have not been able to duplicate Weber's results.

Compiler's comment: Little can be made out of the sparse results obtained so far, but the possibility exists that some hitherto unrecognized force is related to many geophysical phenomena.

SECTION GQ: CRUSTAL MOVEMENTS

Earthquakes are far from being completely understood. Fairly convincing correlations exist between earthquake and solar activity and even the position of the moon. Furthermore, earthquakes are often accompanied by bizarre sounds, lights, and magnetic effects. Some seemingly sound reports connect earthquakes to the appearance of meteors and unusual weather. Such is the stuff of section GQ.

GQE	Earthquake phenomena. Earthquake lights, sounds, odors, and physiological effects on men and animals. Correlations of earthquakes with meteors, fog, darkness, precipitation, etc. (Some earthquake lights are included in GLD.)
*GQF	Fault phenomena. Electrical, magnetic, and thermal anomalies associated with fault lines. Correlation of faults with other geophysical phenomena.
*GQG	Geographical correlations. Predilection of earthquakes and other crustal motions for certain patterns, such as great circles and antipodal relationships.
GQS	Solar, lunar, and planetary correlations. Possible connections between solar activity and earthquakes. Effects of lunar and planetary position. Relation to time of year and time of day.

*This subsection not represented in Volume G2.

GQE-020 EARTHQUAKES AND ELECTRICITY

Parnell, Arthur; Journal of Science, 20:697-706, December 1883,and 21:1-10, January 1884.

This is a wonderful old article, and the author is so convinced of his thesis. Generous sections dealing with specific observations and trends are quoted, but much philosophy has been deleted. It is an excellent period piece.

The present writer is equally impressed with the belief that electricity is the true source of earthquake phenomena, and he had already published his views on the matter (in connection with thunderstorms) before he was aware of the existence of another worker in the same field; and he now proposes to submit a slight historical notice of some of the suggestions that have at different times been advanced in connection with the association between earthquakes and electricity.

The most ancient allusions to the subject are probably those contained in the Scriptures. After the arrival of the children of Israel in the wilderness at the foot of Mount Sinai, on their journey from Egypt to Canaan, "it came to pass on the third day in the morning that there were thunders and lightnings and a thick cloud upon the Mount, and the voice of the trumpet exceeding loud; so that all the people that was in the camp trembled. And Moses brought forth the people out of the camp to meet with God; and they stood at the nether part of the Mount. And Mount Sinai was altogether on a smoke, because the Lord descended upon it in fire; and the smoke thereof ascended as the smoke of a furnace, and the whole Mount quaked greatly" (Exodus xix., 16-18). We thus see how the giving of the Old Law to the chosen people was ushered in by grand physical manifestations; and the thunderstorm and earthquake which they included would appear to be intimately combined in one common source.

Now let us turn to a very different portion of the Holy Writ——to scenes of exquisite imagery foreshadowing by sign and metaphor the eve of a New Law and of a new order of things:——"I saw the seven angels which stood before God; and to them were given seven trumpets. And another angel came and stood at the altar, having a golden censer; and there was given unto him much incense that he should offer it with the prayers of all saints upon the golden altar which was before the throne. And the smoke of the incense which came with the prayers of the saints ascended up before God out of the angel's hand. And the angel took the censer and filled it with fire of the altar, and cast it into the earth; and there were voices and thunderings and lightnings and an earthquake" (Rev. viii, 2-5). Again, "The seventh angel sounded, , . . and the temple of God was opened in heaven, and there was seen in his temple the ark of his testament; and there were lightnings and voices and thunderings and an earthquake and great hail" (Rev. xi., 19). And again, "The seventh angel poured out his vial into the air; and there came a great voice out of the temple of heaven from the throne, saying, It is done. And there were voices and thunders and lightnings; and there was a great earthquake, such as was not since men were upon the earth, so mighty an earthquake and so great" (Rev. xvi., 17, 18). It seems impossible to doubt that the Inspirer of these three passages looked on lightnings and earthquakes as being branches of one and the same agency.

Descending now to secular history we find the following remarkable extract from Pliny's writings, quoted by Alexander Von Humboldt in his famous "Cosmos":

This quotation is in Latin and is not reproduced.

In this last sentence the co-ordination of thunderstorms and earthquakes is clearly recognised. And whilst in ignorance of the existence of the force of electricity, it is by no means unreasonable that the frequent occurrence of earthquakes immediately after a period of sultry atmospheric calm should have originated the idea suggested in the first sentence, that they were caused by the bursting forth of the imprisoned winds. (After all, who knows even now but that winds may in some respect be due to electrical action?)

In modern times it would appear that Dr. Stukeley was the first person who advanced the view that earthquakes were probably caused by electricity. This was on the occasion of the earthquakes that happened in 1749 and 1750, at London and at Daventry (in Northamptonshire) respectively. Stukeley's papers were read before the Royal Society on March 22nd, 1749, and on December 2nd, 1750. He»shows that during these years thunder, lightning, aurorae, and meteors had been remarkably prevalent throughout England, and the whole of his arguments are well worthy of study. But whilst Stukeley was thus urging this theory a philosopher in the South of Europe was at the same time, and without any knowledge of Stukeley's labours, proceeding on the same course. This southern physicist was a native of Turin and a Roman Catholic priest. His name was Giambattista Beccaria. In 1753 he wrote "Dell Elettricismo artificiale e naturale, " and in 1758 "Lettere dell Elettricismo. " If the theory of the electrical origin of earthquakes should ever gain acceptance it is to this great man that the honour should be awarded. Of him the following remarkable testimony is given by his contemporary, the well-known Dr. Priestley:——"All that was done by the French and English electricians with respect to lightning and electricity fell far short of what was done by Signor Beccaria at Turin" (Hist., 315). Again, in regard to experiments made by savants for ascertaining the electricity in the air, "Signor Beccaria made, however, the most extensive and accurate experiments on this subject" (Hist., 338). And again, in connection with the heterodox views of Mr. Wilson regarding pointed lightning-rods, he alludes to Signor Beccaria as one "whose observations and experience with respect to lightning give a weight to his opinion superior to that of any man whatever" (Hist., 373): and this he writes at a time (1775) when Benjamin Franklin was, so to speak, in the zenith of his physical fame. Beccaria appears to have made experiments and researches on Terrestrial electricity for a period of some twenty-five or thirty years, and he became firmly rooted in the belief that not only were lightning-strokes (or thunderbolts) due to the earth's electricity, but that also earthquakes, aurorae, and whirlwinds were derived from the same cause. It is most noteworthy that he, one of the great pioneers of electricity, one of the men who attended at its birth,—— the man who above all his fellows minutely searched into its operations and effects in regard to Nature, and the man who, of all the great labourers in the electrical vineyard (living as he did in Italy, a land which probably far beyond other European lands, gives facilities to the natural philosopher for studying the action both of the thunderbolt and of the earthquake), had the greatest natural opportunities for arriving at the truth,——should have thus deliberately recorded his convictions respecting the electrical source of earthquakes. And it is equally remarkable that these convictions should have been deliberately rejected by almost every one of his contemporaries and successors. For to this day there is hardly a scientific man in Europe who entertains even Beccaria's view as to the earth-sprung nature of lightning-strokes. How then can we expect that, in the absence of this essential preliminary step, the whole development of Beccaria's theory could ever have been adopted?

We have already drawn attention to a great English philosopher of those times, viz., Dr. Joseph Priestley, F.R.S., who wrote "The History and Present

State of Electricity, with Original Experiments, the fourth edition of which appeared in 1775. On the mind of Priestly the researches and opinions of Beccaria had evidently made a strong impression, and it was in no faltering spirit that Priestley supported the views of his great master. The "Queries and Hints" on terrestrial electricity modestly propounded by Priestley are of a very pregnant nature. He says, "May not the void space above the clouds be always occupied with an electricity opposite to that of the earth? And may not the thunder, earthquakes, &c., be occasioned by the rushing of the electric fluid between them whenever the redundancy in either is excessive? Is not the Aurora Borealis, and other electrical meteors which are remarkably bright and frequent before earthquakes, some evidence of this?" . . . "Is not the earth in a constant state of moderate electrification?" . . . "And is it not probable that earthquakes, hurricanes, &c., as well as lightning, are the consequences of a too powerful electricity in the earth?" . . . "Supposing earthquakes to be caused by the discharge of a redundant electricity from the surface of the earth, might they not be prevented in countries subject to them by kites flying very high, and wires in the strings so as to promote an easy communication between the earth and the upper regions of the atmosphere?"—(Hist., 459.)

The next English writer to advert to the question appears to have been William Nicholson, who in 1787 wrote "An Introduction to Natural Philosophy." He adduces experience to combat the idea that earthquakes can be occasioned by subterranean explosions. But apparently he alludes to explosions of vapour, for he mentions the notion as "the common opinion." His notice is valuable as tending to show one of the possible reasons for the rejection, by the physicists of those days, of the theory of an electrical origin; for doubtless the only action they would conceive to result therefrom would be that of a subterranean explosion somewhat akin to a subterranean explosion between two clouds. Since, however (as Nicholson shows) facts demonstrated that the operation of earthquakes was chiefly of a superficial nature, the upheaval of the ground that must inevitably attend an explosion from below was probably deemed to be by no means in accordance with observation, and the electrical theory was therefore discredited. But to physicists of the present day conversant with the important class of electrical discharges known as leaks the surface nature of the action of earthquakes would appear to present a stamp of confirmation, rather than a stumbling-block.

A long interval now ensues, and Humboldt's "Cosmos" would seem to be the next important work that dealt with the question. The English translation (by Colonel, afterwards Sir Edward, Sabine, F. R. S.) of this "Sketch of a Physical Description of the Universe" was published in 1847. Besides the quotation from Pliny to which we have already alluded, much valuable information on the subject of earthquakes is furnished by Humboldt. He says:—"Active volcanoes may be regarded as safety-valves for the country in their immediate vicinity" (i., 202). . . . "The destruction of Lisbon, of Caracas, of Lima, of Cashmeer in 1554, and of so many towns of Calabria, Syria, and Asia Minor, shows that on the whole the most violent shocks do not usually take place in the vicinity of still active volcanoes" (i., 202). In allusion to the substances ejected at times from the earth——such as hot water, steam, noxious gases, mud, smoke, and flames——he says, "Do gaseous fluids issue from the interior of the earth and mingle with the atmosphere? Or are these meteorological processes the effects of a disturbance of the electricity of the atmosphere by the earthquake?" (i., 205). In regard to the association of earthquakes with thunderstorms he says, "On the coasts of Peru, where rain scarcely ever falls, and where hail, lightning, and thunder are unknown, these atmospheric explosions are replaced by the subter-

ranean thunder which accompanies the trembling of the earth" (i., 205). Lastly, in respect of the probable affinity between the heat, electricity, and earthquakes: "If, on the one hand, the internal heat of our planet may be connected with the excitement of electro-magnetic currents and the evolution of terrestrial light aurorae) accompanying a magnetic storm, it is also a principal source of geological phenomena" (i., 189).

A great name in seismological literature now claims our recognition. To the late Mr. Robert Mallet, F. R. S., Science is much indebted for his magnificent record of the earthquakes that have occurred between B.C. 1606 and A. D. 1850——a list that comprises no fewer than 6831 instances of terranean convulsion. This account, together with most of his researches in the field of earthquake physics, is contained in various Reports made to the British Association during the years 1850 to 1854 inclusive. Hereafter we shall present a selection from Mallet's incidents; let us now notice some of his dicta. In regard to particular shocks which have caused fissures to open in the earth, and fire and smoke to issue therefrom, he says:——"The experiments of Becquerel and other electricians have shown that when fracture in a solid takes place a powerful electrical disturbance is the consequence. This will be great in proportion as the surface and mass fractured are in themselves large. When therefore a fracture of a mile long and of many feet in depth is formed, . . . the disturbance of electric equilibrium may be expected to exceed that of a heavy thunderstorm, and may quoad this part of earthquake phenomena realise the dreams of the older philosophers who thought that an earthquake was a thunderstorm under ground. In this then I believe is to be found the usual source of the flame or flash seen suddenly to appear and vanish at the mouth of the rent" (First Report, p. 54). He thinks that the smoke observed is probably in all cases dust. On the subject of the malaise that frequently (as with thunderstorms) precedes earthquakes:——"Animals, including pigs, oxen, horses, mules, dogs, geese, poultry, show presentiments of coming shocks by their uneasy manner. Human beings have sometimes a tendency before shocks to giddiness, headache, and nausea" (First Report, p. 68). He quotes Von Hoff in the following important passage:——"In all relations between this earth and its atmosphere the former is to be considered as the principal and the latter only as its appendage. The atmosphere is the child of the earth, and is supported by it" (First Report, p. 71). And again, in respect of the correspondence between earthquakes and terrestrial magnetism, Von Hoff loquitur:——"In many instances in which an opportunity of observing the magnetic needle during an earthquake has presented itself an alteration in its direction "for the time has been observed. " . . . "More remarkable, however, are the changes in the direction of the dip and variation needles, which take place at a distance from the place where the earthquake was observed, and at a place where the shock itself is not perceptible; as, for instance, in Paris on the 19th February and 31st May, 1822, simultaneously with an earthquake which occurred in Savoy and some of the southern parts of France. If this observation should be established by others carefully made, the existence could not be denied of a connexion between terrestrial vulcanism and terrestrial magnetism. " Mallet himself supplies the following remarkable conception:——"Thus, then, ignorant as we are of all within the outer surface or skin of our globe (and of how much of its exterior, for the ocean shrouds two-thirds of it from our eyes?), we are compelled to see the close connexion of these mighty heating powers in which ignition is present on the vastest scale, yet without combustion, with the forces of terrestrial electricity and magnetism, forces which are those alone that within range of our observation are mutually convertible and both convertible into heat. Currents of both we know are ever passing, with variable activity, through enormous

volumes of the earth's crust, the different parts of which possess very different conducting powers. Can it be that these currents, constrained! to pass through narrow and bad conductors at vast depths in some formations, ignite them in their progress? Will it be found that the great lines of volcanic activity (as dreamed by Bylandt) are in some way connected with those of terrestrial magnetism?——are possibly normals to the surface curves of equal magnetic intensity? A glance at one of Gauss's magnetic maps, and at another of the great bands of active volcanoes on our planet, almost forces the mind into such conjectures" (First Report, p. 77). Yet this brilliant speculation seems to have fallen entirely to the ground, for the author of it consistently attributed the cause of earthquakes either "to the sudden formation of steam from water previously in a state of repulsion from the heating surfaces" (First Report, p. 80), or "to the passage of a wave of elastic compression causing each particle of earth of perform a vibratory movement" (Quart. Rev., July, 1881).

In the British Association Report for 1851 is a communication by Mr. R. Budge, F. R. G. S., regarding the great earthquake which took place in Chili during his residence there in that year. After describing the various circumstances of the event, he states that he cannot understand earthquake phenomena unless electricity be the agent (B. A. R. 1851, p. 85). In the same Association's Report for 1852 the well-known Dr. Buist, of Bombay, in a letter to Prof. Baden Powell, F. R. S., dated July 24th, 1852, says, "It is now well established that in India, at all events, earthquakes are almost always accompanied by furious storms of thunder, lightning, and rain; it is difficult to trace the cause of coincidences so remarkable in the commotions of the earth and the air" (B. A. R. 1852, p. 239) . Again, in this Association's Report for 1864, the Rev. E. B. Ellmar describes a shock that occurred at Lewes, in Sussex, on the 21st August 1864, and was preceded by copious showers (after three months of drought), accompanied by a great wave from N. W. to S. E., and followed by a thunderstorm, with vivid lightning, much hail, and two waterspouts. He then quotes a letter from Dr. Nicholson, of Tramfield, who says that he has frequently experienced shocks in the West Indies after a long drought, and that he is inclined to attribute some of these shocks to electricity as propounded by Dr. Stukeley (B. A. R. 1864, Trans. 16).

In his "Heat considered as a Mode of Motion" (1863) Prof. John Tyndall, F. R. S., quoting Prof. Dove, of Berlin, in regard to the earthquake at Caracas, of March 26th, 1812, graphically depicts Pliny's idea of a force imprisoned beneath the surface of the earth, and struggling to obtain freedom. "March 26th, 1812, began as a day of extraordinary heat in Caracas; the air was clear, and the firmament cloudless. It was Green Thursday, and a regiment of troops of the line stood under arms in the barracks of the Quarter San Carlos ready to join in the procession. The people streamed to the churches. A loud subterranean thunder was heard, and immediately afterwards followed an earthquake shock so violent that the church of Alta Gracia, 150 feet in height, borne by pillars 15 feet thick, formed a heap of crushed rubbish not more than 6 feet high. In the evening the almost full moon looked down with mild lustre upon the ruins of the town under which lay the crushed bodies of upwards of 10, 000 of its inhabitants. But even here there was no exit granted to the elastic forces underneath. Finally, on April 27th, they succeeded in opening once more the crater of Morne Garou, which had been closed for a century; and the earth for a distance equal to that from Vesuvius to Paris rung with the thunder-shout of the liberated prisoner" (p. 172).

The anomymous writer of an article in "Blackwood's Magazine" for July, 1869, entitled "A New Theory of Earthquakes and Volcanoes," must now be noticed. The "new" theory advanced is the electrical origin of earthquakes;

and the writer had evidently neither heard of the labours of Stukeley and Beccaria, nor had he examined the writings of Mallet, Humboldt, and Pliny. The paper is, however, of great interest, and the following are some of the author's conclusions:——"It is the earth which is the chief cause of all our thunderstorms." . . . "The atmosphere plays a secondary role compared with the solid earth."... "It is the condition of the earth's crust which forms the main element of electrical action." . . . "We may aptly describe earthquakes as thunderstorms in the earth."... "Volcanoes are vents which the subterranean electric action makes for itself, or for its effects, in those regions or localities where it is strongest or most permanent." [End of first installment]

In "A Practical Treatise on Lightning Protection," by Henry W. Spang (Philadelphia, 1877), it is stated that Mr. Cromwell Varley, F.R.S. (whose lamented death has recently taken place), was of opinion that some earthquakes are due to subterraneous electrical discharges. He had found that powerful positive currents rushed through the Anglo-American cables towards England a few minutes before and a few minutes after the shocks of March 17th, 1871 (p. 29).

In "Nature" (No. 247, vol. x., 1874) Mr. H. H. Howorth expresses his opinion that the earth is shrinking about its equatorial region, and is being thrust out in the direction of the Poles; and he thinks that the distribution of this force may correspond with that of terrestrial magnetism. He quotes from Dr. Zollner's paper in the "Philosophical Magazine," wherein it is stated that Kriel has given many instances of the coincidence of earthquakes with magnetic disturbances. -Volcanoes are, according to Mr. Howorth, the mediate results of the shrinking of the earth; "earthquakes, on the contrary, are its immediate results, and go far to prove that terrestrial magnetism is to be correlated with the force which is shrinking the earth."

The article in the "Quarterly Review" for July, 1881, already mentioned, states that the most certain characters and accompaniments of earthquakes appear to be their suddenness, the stifling heat and electric state of the atmosphere, and the sudden roar as of distant artillery. Dr. Schmidt, the Government Astronomer at Athens, in his researches on the Grecian earthquakes of 1840 t6^1878, arrives at the result that the great ones had almost invariably a direction from N. E. to S. W. The reviewer says that the same fact has also been noticed in regard to severe shocks in America in 1870; and he then asks "Is not this the line of path habitually followed by electric currents?" After further discussion on the physical action of earthquakes, he says——"Considering the irresistible force, the unmeasured rapidity, the quick repetition, and the long duration of the shocks, what known agent in Nature, we would ask, except Electricity, is capable of producing at the same time such singular effects in the sea and such tremendous results on land?" Lyell and other authors have mentioned, but without laying on the occurrence the stress it deserves, the state of the atmosphere before an earthquake as densely charged with electricity. "The vicinity of hot springs, volcanoes, and mud lakes, regions of intense heat and centres of the electric influence, are the special haunts of the earthquake, and Science has pretty well proved that heat and electricity are convertible." All the circumstances inseparably connected with earthquakes point to the conclusion "that an earthquake is the result of discharges of terrestrial electricity accumulated in the bowels of the earth, which we know to be a reservoir of electric matter." An earthquake shock "is a direct blow not differing probably from that of a lightning stroke." "Even if it be proved that the solid strata beneath the surface and the mountain masses above it are unfavourable to the transmission of electric energy, there are plenty of cracks and fissures in its solid substances through which it may

shoot forth. In the waters of ocean it finds a ready conductor, which accounts for the way in which ships on the sea are affected by it."

The attention of electrical engineers is invited to consider whether it may not be possible to invent some species of apparatus "capable of averting the calamity from its habitual haunts." The reviewer hopes that men of Science intent upon the collection and storage of electric force will not neglect "that storehouse of unlimited energy already filled within the bosom of the earth," and he trusts that they may be able to devise means for preventing the fearful disasters liable to be occasioned by earthquake shocks. We have given but a brief summary of the salient points of this cogently-reasoned paper, which deals with the subject in a very comprehensive manner, and is especially powerful in treating on the geological portion of the question.

In April, 1882, the present writer published a small work on "The Action of Lightning," completed by him in April, 1881. He was unfortunately unaware of the researches concerning the association of electricity and earthquakes made by the authors he has mentioned, or the short allusions made to the subject in his work would probably have been more copious and decided. He ventures, however, to resubmit these few references as being perhaps entitled, in their measure, to take part as links in the chain of literary effort under investigation. The passages are as follows:——"We appear to have prima facie grounds for believing that the earth's surface is really the collecting plate of the terrestrial condenser; . . . but the questions now arise, what is the original source of the earth's electricity? and how does its surface collect it? In our present state of knowledge it seems to be impossible to get beyond conjecture in replying to such questions. Supposing, however, that we take up the opposite view, that the clouds form the collecting plate, the task of attempting to prove how they originate and collect their electricity would appear to be even more hopeless; for although we reasonably infer that the clouds are collectors of electricity, we do not know the fact for certain. . . . But we do know with certainty several important facts regarding the earth's electrical constitution; one is that it is a great holder of electricity; . . . another, that terrestrial disturbances, such as waterspouts, earthquakes, and volcanic eruptions, are connected with the actions of electricity or magnetism." . . . "As to how the earth . . . became a magnet we are practically in total ignorance. The fact, however, that it is simultaneously both a holder of electricity and a magnet is well worthy of attention; and so also is the fact that phenomena undoubtedly electrical, i.e., earth-currents and aurorae, are invariably accompanied by magnetic disturbances." . .• . "May we not conceive the subtle force usually called magnetism to be nothing but electricity, i. e., electricity bound or manifested in a peculiar manner, and magnetism itself as only a property or influence . . . appertaining to certain bodies and permitting this particular manifestation?" . . . "On this principle, then, the earth is a magnetic body like steel or iron, and what is known as its magnetism becomes an additional proof of the presence and activity of its electricity, and strengthens the probability that the globe is itself the originator of thunderstorms and of all other electrical phenomena known to occur in connection with it. That the separated agencies composing this electricity should be in constant motion in the magnetic field or orb from the Equator towards the Poles is what is to be expected; . . . hence . . . we have manifestations of motion (rendered irregular by induction and by geological causes) in the shape of earth-currents. The polar accumulations of electricity . . . would explain the attraction of the earth's poles on those of other magnets. To the same fact of dense accumulation of electricity at or near the magnetic and terrestrial poles . . . would be attributed the manifestations of silent continuous discharges . . . seen under the form of aurorae. And it

is conceivable that the electricities, in their motions . . . towards the poles, are occasionally forced . . . to accumulate for a time at certain places on the surface; and when this should occur in regions where clouds . . . were frequently present, the necessary conditions for the development of thunderstorms would apparently be obtained. Lastly, if the . . . accumulations should occur in certain portions of the earth's crust . . . insulated from each other, and below though not far removed from the surface, and especially in regions where clouds . . . were habitually absent (as in Chili and Lower Peru), there would appear to be possible causes for the occurrence of earth explosions manifested by earthquakes" (pp. 156-160). In regard to the term explosion here used the writer is now inclined to consider the nature of an earthquake discharge as an electrical leak rather than as an electrical explosion.

In the "Athenaeum" of July 8th, 1882, a review of the last-mentioned work was given. The reviewer noticed the portions relative to terrestrial electricity in the following terms:——"The earth-sprung lightnings which so constantly form an attendant phenomenon on volcanic eruptions, and the subterranean thunder which at times resembles the artillery fire of a naval engagement, are at once facts that support the view given in this book of the functions of the terrestrial condenser, and hints that the diligent pursuit of the enquiry may yield much valuable information as to the general theory of electric storms, aerial, super-terrestrial, or sub-terrestrial." . . . "It is from the co-ordination of the indications given by the barometer, the seismometer, and the various appliances for measuring electric and magnetic force and direction, that we must hope to arrive in due time at the true theory of electric storms, of which we take thunder and lightning to be one form and earthquake another."

The last extract in our series is one from an article on "The City of Earthquakes," in the "Atlantic Monthly Magazine" for March, 1883, by Mr. Horace D- Warner, a Civil Engineer who was present at Caracas during the last earthquake there, on September 6th, 1882. It appears that it was accompanied by a coast wave, and that serious damage was almost wholly confined to the river suburb, the higher portions of the town, built on a rocky substratum, being untouched. He says that "a native of Venezuela would laugh at the idea that a terremoto is an upheaval of the ground. The movement of dislodged rocks, the disjointment of house-walls and their way of falling, the motions of a tidal wave during the progress of an earthquake, all prove that the shock is a lateral push." This statement seems to corroborate the idea already suggested, in reference to the writings of Mr. William Nicholson in 1787, that the shock is probably a discharge not of the concentrated nature of an explosion, but rather that due to a sudden escape of accumulated force from the ground over an area of some extent,——a theory to which the facts attendant on electrical leak discharges are eminently favourable.

In order to strengthen the idea of the electrical origin of earthquakes we will now submit a list of some of those events the records of which show that they were preceded, accompanied, or followed, by storms of thunder and lightning. The incidents, unless otherwise annotated, are selected from Mallet's Reports.

These tables are too long to reproduce. They include records of 6 earthquakes preceded by thunderstorms, 45 accompanied by thunderstorms, and 22 followed by thunderstorms.

The year 1750——during which, on September 30th, the shock at Daventry, in Northamptonshire, occurred——was remarkable for thunder and lightning throughout England (Priestley, Host., 356). In 1822 "an extraordinary number of violent thunderstorms, accompanied by earthquakes and simultaneous erup-

tions of Mount Vesuvius, " occurred in France and over a great part of the Continent (Anderson on Lightning, p. 76). In July, 1829, earthquakes occurred in Hungary and in Spain, and remarkable thunderstorms in many parts of Europe (Mallet). In 1880, and again in 1883, thunderstorms and earthquakes were very prevalent in many countries.

To the above lists it may perhaps be interesting to add a few meteorological statistics, gathered from the records of earthquake incidents, collected by the writer for analysis, up to the present date. Most of the manifestations named are probably closely connected with the action of terrestrial electricity. It is to be understood that either shortly before or during, or shortly after the occurrence of shocks, these additional phenomena were among the attendant circumstances. The number of separate earthquake cases from which they are gleaned amounts to 490.

	No. of cases.
Thunder, detonations, and rumblings	156
Isolated rushes or currents of wind, or hissing sounds, giving the idea of an escape of force	31
Waves or commotions of the sea	28
Aurorae	23
Meteors	73
Ignes fatui	2
Lightning flashes in the atmosphere (exclusive of thunderstorms)	15
Flames seen to issue from fissures	10
Magnetic disturbances	22
Tempests, hail, and rain (exclusive of thunderstorms)	62
Whirlwinds	7
Snowstorms	8

GQE-021 EARTHQUAKE IN DOMINICA

Watt, Edmund; Nature, 20:431-432, September 4, 1879.

A severe shock of earthquake was felt here [Leeward Islands] at 1. 20 A. M. yesterday (Sunday) the 10th instant, and at intervals, until 1. 52, there were several tremulous movements of the earth. The noise immediately preceding the first shock reminded me of the clatter which is sometimes heard on board an ocean going steamer in very rough weather, when a heavy sea strikes the ship, and all the crockery laid out for dinner is suddenly thrown from the "fiddles" and broken into pieces on the floor of the saloon.

After the first shock there was an interval of perfect quiet until 1. 30, when subterranean noises like the discharging or booming of distant guns attracted my attention, and then, at intervals varying from two to five minutes' duration, I counted six of these discharges, and following each discharge there came a gentle tremulous movement. Immediately after the last movement, heavy rain fell, and at 1.55 there were several flashes of very vivid lightning accompanied by loud peals of thunder. The rain continued to fall during all yesterday and last night.

GQE-022 EARTHQUAKE PHENOMENA

GQE-022 EARTHQUAKE LIGHTNING

Finkelstein, David, and Powell, James; Nature, 228:759-760, November 21, 1970.

In some parts of the world, earthquakes are often accompanied by ball lightning, stroke lightning and sheet lightning. The only causal connexion that seems possible is that the seismic strains of the earthquake somehow cause an electric field in the air, which in turn produces ball lightning and stroke and sheet lightning. What is the mechanism of this "seismoelectric effect"?

It is suggested by Terada that the streaming potential of subterranean capillary flow of water causes these electric fields. We estimate, however, that the seismic stresses necessary to produce breakdown fields by this mechanism are several orders of magnitude greater than exist during earthquakes. Electrostatic generation by dust, which is probably important in volcano lightning, is not significant in these earthquakes.

We propose that the piezoelectric effect in the Earth's crust causes the electric field.

The only significant piezoelectric constituent of the crust seems to be quartz. The mere presence of quartz is not sufficient; there must be the right kind of long range crystalline order or texture, for example, m3: m or »m. The existence and magnitude of just such order are known from piezoelectric prospecting for quartz-bearing ores. The range of order relevant to the seismoelectric effect is the wavelength of seismic waves ("-2 km). Natural geological structures of this size may exhibit effective piezoelectric coefficients of the order of several per cent that of x cut single crystal quartz.

The long range order implied by these measurements is probably the result of the stress history shared by rocks in one tectonic unit. At the relevant temperatures the z axes of quartz crystals tend to line up along the principal direction (eigenvector) of greatest stress. In one rock, for example, 50 per cent of the z axes are within 6.4 degrees of the principal stress direction. There are several processes which can then order the x axes of the z ordered quartz grains. Secondary stresses may order the flats of quartz grains by mechanical action, thus ordering the x axes up to sense. An ordering of their senses occurs in the elimination of Dauphine twinning by a shift in the direction of principal stress.

In rock with a mean piezoelectric coefficient several per cent that of x cut single crystal quartz, and with typical seismic stress changes 30-300 bars, an earthquake makes an average electric field of 500-5,000 V cm"*-. For distances of the order of half the seismic wavelength, the generated voltage is 5 x 10^ to 5 x 10^ V, which is comparable with the voltage responsible for lightning in storms. The impedance presented to this generator by a thin stratum of conductive soil or by conduction through the rock itself does not significantly load it at typical seismic frequencies.

For example, the North Idu peninsula earthquake of November 26, 1930, the best documented instance of seismoelectricity (over fifteen hundred sightings), occurred in a region with widespread quartz rich lava flows. The geology and petrology of this area have been extensively treated by Kuno; near Mt. Hakone, the approximate centre of earthquake lightning, most of the lava flows contain between 15 and 30 per cent by weight of free silica, usually in the form of quartz. Some rocks contain up to 43 per cent free quartz. The rocks are usually crystalline and rarely glassy. In addition to these lava flows there are many regions with exposed dikes and plugs which contain large amounts of quartz and which have crystallized very slowly. One particular quartz diorite plug north of Mt.

Hakone forms a whole mountain, Yagura-dake, approximately 1 km across. This plug is only a few km north of the active Hakone fault along which there was extensive slippage during the earthquake of November 26, 1930. The whole North Idu region has been undergoing tectonic processes since the late Tertiary with consequent strong regional shearing stresses. Thus we conclude that extensive long range ordering of quartz rich rocks has probably taken place in this region.

These calculations make certain predictions possible. We expect that field measurements will show ground voltage differences in the North Idu region during earthquakes, differences sometimes large enough to cause atmospheric electric discharges. It surprises us that while minute piezomagnetic fields of seismic origin have been explored, no attention seems to have been paid to such gross piezoelectric fields.

There should also be very low frequency electromagnetic radiation from seismoelectric waves ranging from 10 Hz, the approximate upper frequency of seismic waves, to well below 1 Hz, and from transient stress changes at higher frequencies. The seismic waves provide an effective 1 km** antenna carrying a current of some 1 to 10 A with a spectral maximum near 1.5 Hz, the approximate maximum for seismic waves. The radiation takes place into the atmospheric cavity whose fundamental frequency is approximately 7 Hz. Electromagnetic radiation from 1.5 Hz seismic waves will be of low power (<<1 W) but radiation from higher frequency transients will be much more intense.

There will also be electrical precursors to earthquakes resulting from changes in stress near earthquake foci. There is a tradition in Japan of predicting earthquakes, sometimes with great saving of life, from unusual clear sky lightning. It may be possible to put this kind of prediction on a more systematic basis using more sensitive and quantitative electric measuring instruments than earthquake lightning.

GQE-023 EARTHQUAKE AT ANCHOR

Anonymous; Journal of the Franklin Institute, 23:308, 1837.

The following notes, made on board H. M. S. Volage, while at anchor in Callao Roads, during the severe earthquake which occurred in March, 1828, are of considerable interest. We understand, that part of the chain cable of the Volage which was exposed to its effects, from being then in use, is now in the possession of that learned gentleman, Mr. Faraday.

March 30, 1828. The morning clear, and a light breeze from the southward. At 7h. 28m. a black thin cloud passed over the ship, with very heavy distant thunder. At the same moment we felt the shock of a severe earthquake. I should think it continued seventy or eighty seconds. The ship trembled violently, and the only thing I can compare it to is, the ship being placed on trucks, and driven with rapidity over coarse paved ground. The ship was moored with two chain-cables, and on weighing the anchors a few days after, we found 56 links of the best bower cable much injured; the iron had the appearance of being melted, and nearly one-sixth of the link was destroyed. This piece was 30 fathoms from the anchor, and 20 fathoms from the ship. The bottom was soft mud, in which the cable was buried. During the earthquake the water alongside was full of little bubbles; the breaking of them sounded like red-hot iron put into water. The city of Lima suffered considerably, and a

number of lives were lost. This severe shock was felt for nearly one hundred miles north and south of Lima.

Was the black cloud connected with the event in a causal fashion?

GQE-024 THE EARTHQUAKE OF 1811 AT NEW MADRID, MISSOURI

Dudley, Timothy; Smithsonian Institution Annual Report, 1858, Government Printing Washington, 1859. pp. 421-424.

Hot water and "soot" deposits accompany some of the great earthquakes, as the following excerpts demonstrate.

> Where the travelled, beaten road ran one day, on the next might be found some large fissure crossing it, half filled with muddy, torpid water. It was dangerous to travel after dark, for no one knew the changes which an hour might effect in the face of the country, and yet so general was the terror that men, women, and children fled to the highlands to avoid being engulphed in one common grave. One family, in their efforts to reach the highlands by a road they all were well acquainted with, unexpectedly came to the borders of an extensive lake; the land had sunk, and water had flowed over it or gushed up out of the earth and formed a new lake. The opposite shore they felt confident could not be far distant, and they travelled on in tepid water, from twelve to forty inches in depth, of a temperature of 100 degrees, or over blood heat, at times of a warmth to be uncomfortable, for the distance of four or five miles, and reached the highlands in safety, (p. 422)

> The weather was warm and smoky, and had been so for some days, not a breath of air stirring, and so thick and smoky that the Kentucky shore, one mile distant, could not be seen at all. They were in a balmy Indian summer. The morning after the first shock, as some men were crossing the Mississippi, they saw a black substance floating on the river, in strips four or five rods in breadth by twelve or fourteen rods in length, resembling soot from some immense chimney, or the cinders from some gigantic stove-pipe. It was so thick that the water could not be seen under it. On the Kentucky side of the river there empties into the Mississippi river two small streams, one called the Obine, the other the Forked Deer. Lieutenant Robinson, a recruiting officer in the United States army, visited that part of Kentucky lying between those two rivers in 1812, and states that he found numberless little mounds thrown up in the earth, and where a stick or a broken limb of a tree lay across these mounds they were all burnt in two pieces, which went to prove to the people that these commotions were caused by some internal action of fire, (p. 423)

Was this heat of geothermal or electrical origin?

GQE-025 AUDUBON'S ACCOUNT OF THE NEW MADRID EARTHQUAKE

Fuller, M. L.; Science, 21:748-749, May 12, 1905.

The following quotation is from Audubon's journals.

> Traveling through the Barrens of Kentucky * * * in the month of November [1812], I was jogging on one afternoon, when I remarked a sudden and strange darkness rising from the western horizon. Accustomed to our heavy storms of thunder and rain I took no more notice of it, as I thought the speed of my horse might enable me to get under shelter of the roof of an acquaintance, who lived not far distant, before it should come up. I had proceeded about a mile, when I heard what I imagined to be the distant rumbling of a violent tornado, on which I spurred my steed, with a wish to gallop as fast as possible to a place of shelter; but it would not do, the animal knew better than I what was forthcoming, and instead of going faster, so nearly stopped that I remarked he placed one foot after another on the ground, with as much precaution as if walking on a smooth sheet of ice. I thought he had suddenly foundered, and, speaking to him, was on the point of dismounting and leading him, when he all of a sudden fell a-groaning piteously, hung his head, spread out his four legs as if to save himself from falling, and stood stock still, continuing to groan. I thought my horse was about to die, and would have sprung from his back had a minute more elapsed, but at that instant all the shrubs and trees began to move from their very roots, the ground rose and fell in successive furrows, like the ruffled waters of a lake, and I became bewildered in my ideas, as I too plainly discovered that all this awful commotion in nature was the result of an earthquake. * * * The fearful convulsion, however, lasted only a few minutes, and the heavens again brightened as quickly as they had become obscured; my horse brought his feet to their natural position, raised his head, and galloped off as if loose and frollicking without a rider. * * *

Most interesting, of course, is the "strange darkness" preceding the quake.

GQE-026 THE NEW MADIRD EARTHQUAKE

Shepard, Edward M.; Journal of Geology, 13:45-62, February 1905.

> The circumstance of the earthquake has been graphically described by various observers, and an excellent collection of statements in regard to it has been published by Dr. G. C. Broadhead. In order that the phenomena may be more vividly recalled by all, we quote from these extracts:
>
> A letter from L. Bringier, which had been published in the American Journal of Science, Vol. Ill, 1821, states that the shock was felt for 200 miles around. There seemed to be a blowing out of the earth, bringing up coal, wood, sand, etc., accompanied with a roaring and whistling produced by the impetuosity of the air escaping from its confinement, which seemed to increase the horrid disorder of trees being blown up, cracked, and split, and falling by thousands at a time. The surface settled, and a black liquid rose to the belly of the horses, which stood motionless, struck with panic. Afterward the whole surface remained covered with holes, which resembled so many craters of volcanoes, surrounded with a ring of carbonized wood, and sand which rose for about 7 feet. A few months after, these were sounded and found to exceed 20 feet in

depth. Now it is covered with ponds and sand hills or monticules, which are found where the earth was formerly lowest. There seemed to be a tendency to carbonization in all vegetables soaking in the ponds, produced by these eruptions. A lake was produced 27 miles west of the Mississippi, with trees standing in the water 30 feet deep.

Another interesting account of the earthquake is given by Godfrey LeSieur, an old inhabitant of New Madrid County. He says that——

The first shock came at 2 a. m., December 16, 1811, and was so severe that big houses and chimneys were shaken down, and at half-hour intervals light shocks were felt until 7 a. m., when a rumbling like distant thunder was heard, and in about an instant the earth began to totter and shake so that persons could neither stand nor walk. The earth was observed to roll in waves a few feet high, with visible depressions between. By and by these swells burst, throwing up large volumes of water, sand, and coal. Some was partly coated with what seemed to be sulphur. When the swells burst, fissures were left running in a northern and southern direction, and parallel for miles. Some were 5 miles long, 4-1/2 feet deep, and 10 feet wide. The rumbling appeared to come from the west and travel east. Similar shocks were heard at intervals until January 7, 1812, when another shock came as severe as the first. Then all except two families left, leaving behind them all their property, which proved to be a total loss, as adventurers came and carried off their goods in flat boats to Natchez and New Orleans, as well as all their stock which they could not slaughter. On February 17 there occurred another severe shock, having the same effect as the others, and forming fissure s and lakes. As the fissures varied in size, the water, coal, and sand were thrown out to different heights of from 5 to 10 feet. Besides long and narrow fissures, there were others of an oval or circular form, making long and deep basins some 100 yards wide, and deep enough to retain water in dry seasons. The damaged and uptorn country embraced an area of 150 miles in circumference, including the old town of Little Prairie [now called Caruthersville], as the center, a large extent on each side of Whitewater, called Little River, also both sides of the St. Francis in Missouri and Arkansas. Reelfoot Lake, in Tennessee, sank 10 feet. (pp. 46-47)

GQE-027 EVIDENCE OF LONG-PERIOD ACOUSTIC-GRAVITY WAVES LAUNCHED INTO THE F REGION BY THE ALASKAN EARTHQUAKE OF MARCH 28, 1964

Row, Ronald V. ; Journal of Geophysical Research, 71:343-345, January 1, 1966.

Evidence of disturbances to the ionosphere caused by the Alaskan earthquake of (0336 UT) March 28, 1964, have been published recently by Leonard and Barnes and Davies and Baker. The data presented by both pairs of authors are shown to be mutually compatible. It is suggested that the large long-period disturbance seen on Doppler records at Boulder and vertical sounder ionograms at Boulder and other locations are a manifestation of long-period ducted acoustic-gravity waves launched into the ionosphere near the epicenter.

The coupling of earthquakes to the ionosphere may be connected with some of the luminous, electrical, and magnetic effects sometimes reported.
The light flashes and aurora-like displays seen during, after, and before some earthquakes and collectively called "earthquake lights" may be related to the ionization effects described above.

GQE-028 HOW EARTHQUAKES AFFECT ANIMALS

Anonymous; American Review of Reviews, 69:103, January 1924.

While our modern seismographs are extremely delicate, registering the most minute vibrations of the crust of the earth, there are certain phenomena connected with earthquakes, according to a recent investigator, which they are incapable of recording. Among these are the biological effects produced upon animals, which are all the more interesting since they are frequently manifested before the shock itself is registered. This curious circumstance suggests the uneasy forebodings experienced according to some observers by various animals considerably in advance of an electrical storm.

In the Journal of Comparative Psychology Dr. Hans von Hentig of Munich gives the results of his studies upon this subject, which is of peculiar interest just now because of the vast cataclysms which have occurred within the last twelve or fifteen months, first in the New World and then in the Old. In the observer's experience both dogs and foxes frequently display great restlessness a considerable time before the occurrence of an earthquake. At other times on the contrary they exhibit a striking lethargy, animals ordinarily keen sensed and alert appearing to be stupefied. Definite mental disturbances are often found——for example, both the aggressiveness and the personal devotion of a dog to his master may be greatly enhanced during the tremor. Cats likewise often caterwaul with almost unbearable intensity before the beginning of an earthquake, pressing themselves close against their masters or even against entire strangers.

In one case a mother cat fetched her young ones as if seeking for human help. Even hares appear to be so altered as to show no fear of human kind. Horses are extraordinarily affected, sometimes throwing off the rider, even when the latter had not himself felt the tremor of the earth.

Herr von Hentig also tells us that after severe earthquakes the natives of the Sunday Islands are accustomed to throw away the eggs under brooding hens, since they are certain to contain dead chicks. This observation by the way is one recorded by Pliny as occurring after storms. Fish appear to be greatly excited by earthquakes, leaping madly above the surface of the water, and the author is disposed to think that this has much to do with the singular migrations often observed among fishes and the fact that many erstwhile good fishing grounds, such as the North Sea, may be inexplicably deserted for a term of years.

Crocodiles, which are ordinarily as mute as lizards, go roaring down out the bed of the river to take refuge in the primeval forest, a thing actually seen by Alexander von Humboldt. In Cuba a tame house snake is kept which flees into the open before every earthquake, thus giving warning to the house dwellers. Bees are extremely sensitive to earthquakes, leaving their hives in great excitement long before the shock is felt, quieting down only after the earthquake has passed over.

Dr. von Hentig concludes that animals do not possess any true "premonition" but that when a sliding or displacement in the earth-crust takes place energies are set free which are perceived by the sensory apparatus of animals. In his belief these physical phenomena both precede and follow as well as accompany the actual trembling of the earth.

GQE-029 EARTHQUAKE PHENOMENA

GQE-029 NOTICES OF EARTHQUAKE SHOCKS FELT IN GREAT BRITAIN——

Milne, David; Edinburgh New Philosophical Journal, 35:pages as noted, 1843.

In many of the reports which have been quoted, notice is taken of impressions still more peculiar, as connected with the earthquake-shocks.

A feeling of nausea was experienced by many individuals, and which is variously described as resembling "sea-sickness, "——"sickness, like that felt before fainting"——"uneasy sensation, which I can compare only to the first disagreeable feelings which usually precede a fit of sea-sickness, "——"a most peculiar sickish sensation, such as I never felt before. "

Headaches were produced, as attested by the Rev. Mr. Walker on the 12th October, by Mr. Rutherfurd, W. S., on the 14th October 1839, and by Mr. Young of Crieff, on the 23d October 1839, all of whom ascribe these as the effects of shocks which occurred on these days.

Nervous sensations of a more indefinite kind are spoken to by various individuals. On the 14th October 1839, at the moment that the shock occurred, an individual, though he was not aware of its occurrence, experienced "an unusual feeling, which led him to suppose that some illness was impending. " Mr. Robertson, who felt the shock of 16th October at Glendevon, on the north side of the Ochils, says,——"I remember having just before, felt as if some strange presence had been silently gathering round me, and could not be shaken off.'' Mr. Laurie, the parish schoolmaster of Monzie, says, "the shock of the earthquake on 23d October, affected the nerves disagreeably, and left a painful impression. It reminds me vividly of the shock from an electric machine. "

The conviction of there having been an electrical discharge, was decidedly entertained by a number of individuals. Thus, at Alva, near Tillicoultry, two clergymen felt as if electrified. Mr. Jeffrey, who felt the shock in the Carse of Falkirk, says,——"I may mention a circumstance which I have not seen taken notice of in any account of the late earthquake, and it is, that I am convinced it was accompanied with an electric shock. I was perfectly calm and collected at the time when it came on, and never had any doubt of what it was, nor was I at all alarmed for the consequences. But the feeling produced upon my body, was exactly similar to what an electric shock has in other circumstances had upon me." Mr. Stein, surgeon at Menstrie, near Stirling (in a report not before quoted), says, "I think the atmosphere (on the 23d October 1839) was highly charged with electricity, both before and at the time when the shock occurred." He speaks of "the slightly redened or lurid appearance of the atmosphere towards the S. and SE., particularly observable for several evenings preceding the shock of the 23d. (pp. 151-152)

GQE-030 THE MENTAL EFFECT OF EARTHQUAKES

Anonymous; Popular Science Monthly, 19:257-260, June 1881.

No physical phenomena, however dreadful, seem to produce the same sense of paralysis as earthquakes. A correspondent of Captain Basil Hall, who was in the earthquake of Copiapo, in 1822, describes the effect on the mind as something which begins before any other sign of the earthquake has manifested itself at all——an anticipatory horror, which is even more marked in the case

of the lower animals. "Before we hear the sound, or at least are fully conscious of hearing it, we are made sensible, I do not know how, that something uncommon is going to happen; everything seems to change color; our thoughts are chained immovably down; the whole world appears to be in disorder; all nature looks different to what it is wont to do; and we feel quite subdued and overwhelmed by some invisible power, beyond human control or apprehension." In the Neapolitan earthquake of 1805, these anticipatory signs were most remarkable in relation to the life of the animal world. An Italian writer, quoted in Mr. Wittich's "Curiosities of Physical Geography," says: "I must not omit in this place to mention those prognostics which were derived from animals. They were observed in every place where the shocks were such as to be generally perceptible. Some minutes before they were felt, the oxen and cows began to bellow, the sheep and goats bleated, and, rushing in confusion one on the other, tried to break the wicker-work of the folds; the dogs howled terribly, the geese and fowls were alarmed and made much noise; the horses which were fastened in their stalls were greatly agitated, leaped up, and tried to break the halters with which they were attached to the mangers; those which were proceeding on the roads suddenly stopped, and snorted in a very strange way. The cats were frightened, and tried to conceal themselves, or their hair bristled up wildly. Rabbits and moles were seen to leave their holes; birds rose, as if scared, from the places on which they had alighted; and fish left the bottom of the sea and approached the shores, where at some places great numbers of them were taken. Even ants and reptiles abandoned, in clear daylight, their subterranean holes in great disorder, many hours before the shocks were felt. Large flights of locusts were seen creeping through the streets of Naples toward the sea the night before the earthquake. Winged ants took refuge during the darkness in the rooms of the houses. Some dogs, a few minutes before the first shock took place, awoke their sleeping masters, by barking and pulling them, as if they wished to warn them of the impending danger, and several persons were thus enabled to save themselves." What it is, before the sound or shock of earthquake is felt, which warns both animals and human beings of the approach of some dreadful catastrophe threatening the very basis of their existence, no one, of course, can say, since the impression made upon the nervous system is, at least as regards our own species, evidently one of general disturbance, and not one to which experience attaches any explicit significance. It may be, of course, that some very great change in the magnetic conditions of a spot threatened with earthquake leads to that extreme excitement of mind exhibited by all living creatures previous to the onset of the earthquake. That, however, is pure conjecture. What is interesting is, that a certain blank consternation seems always to be the characteristic herald of an earthquake, as well as the characteristic result. That it should be the characteristic result is, of course, no wonder. The very condition of human life is the solidity of the not very thick earth-crust on which we live, and when that solidity is exchanged for positive fluidity, as it is in the worst earthquakes, it is natural enough that stepefaction should be the result.

The remainder of the article is mainly philosophical in nature with some description of the destructive consequences of earthquakes, concluding as follows:

Morally, then, the only use of earthquakes must be to <u>test</u> the growth of a spiritual faith in a world and life beyond the reach of earthquakes. Clearly it can not strengthen or educate such a faith. It can only sift the false faith from the true, and accord to the true its triumph.

GQE-031 EARTHQUAKE PHENOMENA

GQE-031 SOME RECENT EARTHQUAKE THEORIES

Gill, H. V. ; Nineteenth Century, 63:144-150, January 1908.

The only unusual ideas (for the year 1908) expressed in this article are: (1) the connection of earthquakes with motions of the poles, and (2) the symmetrical locations of earthquakes.

One of the first fruits of this detailed accumulation of facts is the relationship indicated between the occurrence of earthquakes and other natural phenomena. Thus it has been shown that earthquakes are somewhat more frequent at full moon than at half-moon, and when she is near the earth than when she is far off. They are also more frequent at the equinoxes than at the solstices. In these cases the difference is, however, slight, but the result is of importance as confirming the generally accepted view that the sun and moon produce in the solid crust of the earth a small tide-like effect. Other connections have also been detected, such as that with temperature, magnetic phenomena, the aurora, barometric variations, seasons of the year and times of the day and night, all of which have been shown to be more or less marked. However, the one which is of special interest for us in the present consideration is the close, though not very obvious connection which has been shown to exist between certain motions of the earth's poles and the frequency of earthquakes.

These movements may be illustrated by the uneven running of a machine when the fly-wheel is not well balanced, or even better by the erroneous path of a 'bowl,' due to the bias. Some interesting calculations have been made of the amount of pole displacement which could be produced by modifications in the present distribution of sea and land on the earth's surface, and Sir G. H. Darwin finds that the pole might be moved through several degrees. Lord Kelvin calculated that an elevation through 600 feet, of a portion of the earth's surface having an area of 1000 square miles, and ten feet thick, would alter the position of the earth's axis by 0.3" (about thirty-four feet). At first sight these may seem small quantities in comparison with other astronomical numbers, but the mass of the earth which is shaken is very great, so that the amount of energy involved is enormous. We shall see presently that in the case of large earthquakes very much greater masses may be in question.

Some twenty years ago Professor Milne called attention to the relationship that appeared to exist between the frequency of earthquakes and irregular movements of the poles. He has given much attention to the examination of these phenomena, and, as the result of a very careful and exhaustive investigation, has arrived at the conclusion that the years of greatest pole movements are also years of maximum earthquake frequency, and conversely, that great seismic activity seems to be followed by more marked pole displacements. Sir G. H. Darwin suggested that earthquakes tend to adjust the figure of the earth to one of equilibrium about its instantaneous axis.

From the considerations we have already dealt with it is clear that the principles thus illustrated may be applied to our globe. The sudden disturbance of a large tract of the earth's surface corresponds to the addition of a ball to the hollow top, and the same causes that tend to send the other ball to the opposite side would, in the case of the earth, cause disturbances in other places symmetrically placed with regard to the original earthquake; these

remarks apply particularly to places near the equator. It must be remembered that the case of the earth is not as simple as that of the top, since gravitation must be taken into account, and also for the fact that the total mass remains constant in the same circumstances. However, mathematical investigations show that a subsidence for example at one place will tend to produce a counter disturbance in a corresponding locality. The simplest case would be that of two disturbances at opposite ends of a diameter following closely on each other. A more unusual occurrence would be three disturbances in places equally distant. These views were first suggested with reference to the latter phenomenon.

The month of April 1906 was remarkable for three great disturbances. A serious eruption of Vesuvius took place on the 8th; on the 14th a very severe earthquake occurred in Formosa; while on the 18th San Francisco was destroyed. These three places are not only on almost the same parallel of latitude, but are as nearly as possible equally distant. These circumstances, together with the fact that they all took place within a few days of each other, suggested the possibility of there existing, among them, some such connection as that already pointed out. In a word, the position of San Francisco is such that, in this view, an earthquake in that quarter of the globe was an event to be anticipated with some degree of probability. That such an event could be foretold is not suggested, but, as we shall see presently, a probability of a disturbance in that part of North America could have been scientifically indicated.

In the meeting of the British Association already mentioned, Professor Milne dealt at some length with the theory set forth above, and stated the result of an examination of the Shide (I. of W.) records made by him to test the evidence afforded by past great earthquakes in favour of that view. His researches seem to indicate a very remarkable agreement between facts and theory. His conclusion had best be given in his own words:

To test whether the members of the groups exhibit some symmetrical distribution in space corresponding to that proposed, the earthquakes which have originated in districts separated from each other by 180 degrees in longitude, but on the same latitude, have been compared with each other. . . . In 1899 and 1905, which are years when the geographical distribution of origins exhibited marked differences, 126 earthquakes were recorded. Twenty of these districts. . . . The average interval between the occurrence of earthquakes such as are here considered has, during the last six and a half years, been seventy-two hours, and nearly all have originated from the ten districts. One inference from this is that the distribution in time and space of the above ten pairs may not be anything more than chance. Whether this is to be accepted as generally true remains to be determined by a more complete and extensive analysis of registers. Not only should large earthquakes be compared with their kind, but also with small earthquakes and volcanic eruptions.

A few cases of triplets could also be pointed out. From these facts it follows that in the districts mentioned there would have been some foundation for the belief that an earthquake in the corresponding district might occur; arguing merely from the figures just given the chances against such an event were about ten to one. No doubt if smaller shocks had been examined as well as volcanic eruptions many more instances would be found. It is interesting to note that the earthquake at Valparaiso on the 17th of August in the same year 1906 was followed a few days later by one in North-west Australia; and a shock in the Dutch West-Indies on the 27th of September by one at Calcutta on the 29th. These places are exactly opposite each other, and on the same parallel.

GQE-032 EARTHQUAKE PHENOMENA

GQE-032 [EARTHQUAKES CAUSE EARTH'S WOBBLE]

Anonymous; Nature, 93:276, May 14, 1914.

> The Rev. H. V. Gill has sent us a reprint of his paper read at the last meeting of the British Association on the distribution of large earthquakes in time and space. Mr. Gill's theory is that a great mass-displacement of the crust, such as occurs during a violent earthquake, gives rise to a "wobble" or unevenness in the rotation of the earth, which is neutralised by other mass-displacements occurring either in a distant region or regions symmetrically placed along the great circle through the origin, or of displacements in the opposite direction in the neighbourhood of the origin. To test this view, he has examined the distribution of the 889 world-shaking earthquakes recorded by the seismological committee of the British Association. He finds that 674 (or three out of every four) great earthquakes occurred in groups, successive members of which were separated by a week or less, while the remaining 215 were isolated disturbances. Of the former, 163 (or 18. 6 per cent, of the whole) belonged to groups of two or more earthquakes occurring at different places symmetrically situated with reference to the origin of the first earthquake of a group; 511 (or 57.1 per cent) were members of groups occurring at or near the same place. No attempt, however, is made to show that the displacements of individual groups of the latter class occurred in opposite directions.

Obviously, the causal connection between earthquakes and the earth's wobble is by no means a modern one.

GQE-033 EARTH'S SPEED CHANGED BY ITS PALPITATIONS

Anonymous; Literary Digest, 100:32, February 9, 1929.

> This winter's violent quakes may be due to shrinkage of the earth's crust, speeding up its rotation, we are told by Dr. E. E. Free, in the New York Evening Post. That the earth's speed of rotation does alter, has been established, he says, by measurements made under the auspices of Prof. E. W. Brown, a Yale astronomer. Writes Dr. Free:
>
> "The fundamental things to be remembered in connection with earthquakes is that they are periodic. There are times when there are many, and times when there are few. And nobody knows why.
>
> "The theory that now holds ground as to their causation is that the speed of the rotation of the earth varies slightly from time to time. The law of this variation has not been determined. It amounts to only a small fraction of a second per year, but that small fraction, it is believed, is due to a contraction or expansion of the earth's crust. This speed has been measured astronomically by Dr. Ernest W. Brown, Sterling Professor of Mathematics at Yale University, who has done the most notable work in this field.
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> "As to what can be producing this, the most reasonable hypothesis shared by most experts is that the size of the earth's diameter changes slightly from time to time. This brings about an acceleration of rotation by the principle of the conservation of angular momentum.

"It is best explained in this way: If you take any spinning fly-wheel and make it shrink, it will revolve more rapidly. Again, if you can induce a planet to take a smaller orbit, its speed will increase.

"If the equatorial diameter of the earth increases so much as a fraction of an inch, the earth will move more slowly and, accordingly, if the equatorial bulk decreases, the earth will move more rapidly.

"There is a good deal of evidence to indicate that this variation is accompanied by an increase and decrease in the number of earthquakes. It is a reasonable assumption, therefore, that the shrinking and swelling of the earth's crust set up a strain in the mass, which anybody can see would produce convulsions."

GQE-034 EARTHQUAKES AND THE EARTH'S WOBBLE

Manshina, L., and Smylie, D. E.; Science, 161:1127-1129, September 13, 1968.

It has been known for over 80 years that the earth's axis of rotation moves with respect to an observatory coordinate system. To earthbound observers this represents a variation of the astronomically determined latitude. Viewed from space, it represents a wobble of the earth about its rotation axis. The observed motion is most conveniently displayed as the path of the instantaneous north pole of rotation.

In 1891, S. C. Chandler isolated a component of a 14-month period from the latitude observations. Rigid-body dynamics gives a 10-month period for the earth's natural wobble, but the longer observed period can be reconciled with theory if allowance is made for rotational deformation. The motion is now called the Chandler wobble. The accompanying rotational deformation implies that the Chandler wobble must be subject to damping, and therefore a more or less continuous excitation is required to maintain it. Identifying the source of the excitation has remained one of the principal problems in studies of the earth's rotation. We now report evidence in support of theoretical calculations which led to the hypothesis that large earthquakes provide the hitherto unidentified excitation, (p. 1127)

A connection between earthquakes and the motion of the pole had been suggested very early in the history of latitude observations. Until recently the displacement fields of even the greatest earthquakes were thought to extend to no more than a few hundred kilometers from the focus. Thus, estimates of the contribution of earthquakes to the Chandler wobble excitation fell several orders of magnitude short of the observed level.

The prevailing view on the extent of earthquake displacement fields was drastically altered by the work of Press. Both the theoretical predictions of elasticity theory and distant strain measurements were adduced to argue that a measurable displacement field may extend to epicentral distances of several thousand kilometers for a great earthquake.

When the effect of such large-scale deformation of the earth was calculated for a number of individual earthquakes, and when an estimate of the cumulative effect was made on the basis of earthquake statistics, it was found that earth-

quakes could account for both the excitation of the Chandler wobble and a slow secular shift of the mean pole of rotation (p. 1127)

GQE-035 WHY CHANDLER WOBBLE?

Anonymous; Nature, 227, 889, August 29, 1970.

What follows is a nice summary of the wobble-earthquake question as of 1970.

> Although the Chandler wobble, the precession of the Earth's axis of figure about the axis of rotation, was discovered in 1891, its cause is still a mystery. There are, in fact, two separate puzzles involved——the source of the excitations which produce the wobble of amplitude about 0. 5", and the width of the spectral peak which indicates that the period of fourteen months varies within + 4 per cent. The simplest explanation for the varying period is that it results from continuous excitation of a mechanical system whose natural period changes with time; but it is unlikely that physical changes in the Earth would produce the observed variations over times as short as a year. Alternatively, the Earth could have a fixed Chandler period produced by random excitations which are subject to damping. This is much more reasonable, especially as theoretical calculations of the period turn out to be about 1. 20 years.
>
> But what energy source maintains the random oscillations? During recent years it has become popular to imagine that this source is earthquakes; and this view has received considerable support from theoretical calculations which show that, given the right conditions, one large earthquake could produce 10 per cent or more of the observed Chandler wobble amplitude. If a single earthquake can do this, it seems intuitively likely that all earthquakes together could account for the whole of the Chandler wobble. Ben-Menahem and Israel (Geophys. J., 19, 367; 1970), however, are more pessimistic. They show that a single shallow earthquake of magnitude 8. 5, occurring at a suitable latitude and with a favourable strike-azimuth, could maintain the Chandler wobble for about a year —and yet they conclude, paradoxically, that the total number of real earthquakes could account for only about 30 per cent of the observed wobble amplitude and corresponding secular polar shift.
>
> The reason is, of course* that the secular polar shift produced by an earthquake is critically dependent net only on the shock's magnitude but on its position and its strike and source parameters. An earthquake of magnitude 8. 5 may maintain the Chandler wobble for a year under optimum conditions; but an earthquake of that magnitude only occurs about once every 4 years, and when it does the conditions for Chandler excitation are far from optimum. If all the annual seismic energy were to be released in a single shallow strike-slip rupture on a meridional fault located at the equator, then again the resulting annual shock would be sufficient to drive the Chandler wobble for ever. In practice, circumstances are far less favourable.
>
> It is important to realize, however, that Ben-Menahem and Israel have derived their conclusions from a mathematical model. It turns out to be a model which is considerably more favourable to the excitation of Chandler wobble by earthquakes than models previously used to describe the same effect—but it is a model none the less, and is therefore subject to simplifying assumptions. Thus Ben-Manahem and Israel have not proved conclusively that earthquakes do not account for Chandler wobble because some assumptions may not be valid and modifying conditions may remain to be discovered. For this reason, we have certainly not heard the last of earthquakes as the source of Chandler wobble.

GQS-001 ON REMARKABLE LUNAR PERIODICITIES IN EARTHQUAKES, EXTRAORDINARY OSCILLATIONS OF THE SEA, AND GREAT ATMOSPHERICAL CHANGES

Edmonds, Richard, jun.; Report of the British Association, 20-22, 1845,

The following nine days remarkable for earthquakes, extraordinary oscillations of the sea, or very unusual states of the atmosphere, occurred near the moon's first quarters, at successive intervals of about four lunations each.

1842, November 9.——Earthquake at Montreal and other parts of Canada, when "the waters of the St. Lawrence were violently agitated." This was the day before the moon's first quarter. On the 11th, the day after it, the barometer at Penzance was 29.00, lower than for 247 days before the 13 days afterwards.

1843, March 10.——Earthquake at Manchester; barometer at Chiswick on the preceding days 30.380, higher than for 49 days before and 179 days after.

July 5.——Extraordinary oscillation of the sea in Penzance, Plymouth, Scotland, &c, and a great thunderstorm throughout the island. Barometer at Penzance at the time of the oscillation there 29.50, lower than for twenty-five days before and forty-seven days after. Thermometer at Chiswick 88°, at Brighton 78°, the maxima for the year at those places.

October 30.——Similar oscillations of the sea at Penzance and Plymouth. Barometer at Penzance at the time of the oscillation 29.00, which, except the minimum of the 27th, was lower than for 223 days before and 115 days after.

1844, February 26.——Barometer at Chiswick 28.624, lower than for 409 days before and ever since. At Penzance it was 28.50, having fallen nearly two inches in thirty-six hours.

June 23.—An unusually severe and protracted thunderstorm this evening throughout Cornwall and in Dumfries-shire, and on the following morning at Boston and Liverpool, at which latter place "pebbles and smalt eels descended in the streets." Thermometer at Cheswick on the 23rd, 91°; highest for the year except one day in July. In the weekly meteorological report from the Greenwich Observatory, it is stated as an extraordinary fact, that "at 1 o'clock P. M. (of the 23rd) a thermometer placed on a small piece of raw wool in the sun's rays, rose in seven minutes to 155°, and was still rising when the thermometer was taken away."

October 18.——The town of Buffalo on Lake Erie almost destroyed by a hurricane. This was the day of the moon's first quarter, and almost exactly twenty-four lunations after the earthquake in that neighbourhood already mentioned. At Chiswick this day the maximum of the thermometer was less by 3° than for several months before, and the barometer on the 16th was at a minimum of 28. 940, lower than since the 26th of February.

1845, February 12.——The greatest cold experienced in England probably during the present century. Thermometer at Blackheath, at half past 7 A. M., 33-1/2° below the freezing-point; at Chiswick 35° below that point. Barometer at the latter place 30. 409, higher than for nine months before, except on the 21st of December.

June 13,——Extraordinary oscillation of the sea in Kent, and a "terrific" thunderstorm at Chatham. The temperature very high in all parts of England; thermometer at Penzance being 77°, higher than on any other day of the year hitherto.

Not one of the phaenomena for which the above nine days are remarkable, was forty-eight hours from the moon's first change or quarter. Three of the

days were each at the moon's first quarter nearest the solstice; of these the first and last were distinguished for extraordinary oscillations of the sea, while all were remarkable for great thunderstorms and unusually warm weather.

The author's attention was drawn to the interval of four lunations by having remarked that interval, or 118 days, between the two oscillations of the sea, at and after the great earthquake of 1755, and 119 days between those at and after the great earthquake of 1761.

But while such remarkable days have occurred at intervals of four lunations, others were mentioned as having taken place at intervals of either single lunations or some multiple of a lunation; and the great earthquakes throughout Mexico on the* 9th of March and the 7th of April last, are almost exactly one lunation from each other. So also, in reference to the six known shocks of the earth and extraordinary oscillations of the sea in Cornwall during the last century, the interval between any two of them is almost exactly some multiple of a lunation. The same observation applies to the six which have occurred in the present century, except that of the 20th of October 1837. With this single exception they have all happened at or near the moon's first quarters.

From the facts above noticed, it would appear that an earthquake or any very disturbed or extraordinary state of the atmosphere, is generally preceded or followed either by other earthquakes, or by unusual states of the atmosphere occurring at intervals of single lunations, or of some multiple of a lunation; and that the phaenomena which happen at intervals of four lunations, are more striking than those at the shorter periods. There seems reason therefore for supposing that earthquakes and great atmospherical changes are in many, if not most instances, occasioned principally by the action of the moon.

GQS-002 THE CORRELATION OF DEEP-FOCUS EARTHQUAKES WITH LUNAR HOUR ANGLE AND DECLINATION

Stetson, Harlan T. ; Science, 82:523-524, November 29, 1935.

Certain small variations in latitude previously announced and corresponding small changes in longitude show'an apparent correlation with the hour angle and declination of the moon. The possibility of such small changes in geographical coordinates being associated with tidal phenomena in the earth's crust suggested a renewed study of seismic phenomena as a function of the moon's position. Recent results of Davidson have indicated a connection between the frequency of earthquake aftershocks and the phases of the moon. Investigations by Father Rodes have shown an apparent increase of seismic disturbances with the moon near perigee as compared with the moon near apogee. Some two thousand earthquakes have recently been investigated here from the point of view of a possible correlation of the frequency of their occurrence with the moon's position referred to the epicenter at the time the shocks occur. These studies have also included the relation of both major and minor earthquakes to the magnitude and direction of the tidal forces operating in the region of the epicenter at the time of the occurrence of the seismic disturbances concerned. While the treatment of all earthquake disturbances indiscriminately in such a study may be open to question, and the investigations thus far have yielded somewhat conflicting results, nevertheless a study of deep-focus earthquakes whose epicenters lie more than one hundred kilometers below the earth's surface has yielded a surprisingly striking correlation between the frequency

of these deep-focus quakes and the horizontal components of the lunar tidal forces in operation at the time.

One hundred and twenty-two well-determined deep-focus earthquakes, taken from a list furnished me by Dr. J. A. Sharpe, of the Massachusetts Institute of Technology, have furnished the material for the results summarized in Table 1. This selected list includes only those earthquakes whose depth of focus exceeds one hundred kilometers and for which an ample number of reliable observations have been secured. In Table 1 is listed the number of occurrences of these deep-focus quakes for twenty-four equal intervals corresponding to hourly values in the changing hour angle of the moon referred to the epicenter at the time of the occurrence of each deep-focus earthquake.

Table 1

Table Showing Relation of Frequency of Deep-focus Earthquakes to the Lunar Hour Angle

Hour angle of moon	Number of quakes	Hour angle of moon	Number of quakes
0	7	12	3
1	2	13	4
2	3	14	5
3	5	15	9
4	8	16	9
5	5	17	6
6	8	18	5
7	6	19	9
8	1	20	2
9	2	21	2
10	0	22	5
11	5	23	2
12	3	24	7

It seems hardly conceivable that the gravitational lunar tidal forces of the order of 10^{4} dynes/cm can be sufficient to be any major cause for the high energy disturbances recorded. The significance of the curve relationships herewith shown may offer some new evidence for the hypothesis of trigger action, or furnish a basis for further speculation as to other causes which may be dependent on the lunar period.

GQS-003 MICROEARTHQUAKES AT ST. AUGUSTINE VOLCANO, ALASKA, TRIGGERED BY EARTH TIDES

Mauk, F. J., and Kienle, J.; Science, 182:386-389, October 26, 1973.

Compiler's Summary: Microearthquake activity at St. Augustine volcano, in the Aleutians, both before and after minor eruptive activity on October 7, 1971, showed diurnal peaking. The predominant phase condition showed a one-hour time delay from the time of maximum tidal acceleration. A second phase delay of five hours correlated well with maximum oceanic tidal loading. Correlation of individual peaks of swarm activity suggested that tidal stresses might require preferential orientation for most effective triggering.

GQS-004 SOLAR, LUNAR, AND PLANETARY EFFECTS

GQS-004 THE RELATION BETWEEN THE PERIODIC CHANGES OF SOLAR ACTIVITY AND THE EARTH'S MOTION

Halm, J.; Nature, 61:445-448, March 8, 1900.

Herein is summarized some early work connecting sunspots and the motion of the earth. Later, of course, the earth's wobble was associated with earthquakes and other geophysical phenomenon.

One of the most interesting questions arising from the problem of the sun's activity is that of a possible connection between the varying display of forces on the solar surface and certain phenomena on our planet. The evidence which has been gradually accumulating can hardly fail to convince us of the existence of an intimate, though still mysterious, relation between some of the manifestations of the earth's magnetic forces and the state of dynamic action on the sun. Not only the extraordinary coincidences repeatedly recorded between solar eruptions and terrestrial magnetic storms, but still more the striking synchronism between the varying frequency of solar spots and the observed changes in the display of aurorae, and in the daily oscillations of the magnetic needle clearly point to that conclusion. Scarcely less certain seems to be the fact, confirmed by many recent investigations, that a greater or less disturbance of the sun's surface is attended by corresponding effects upon terrestrial temperature, rainfall, and other meteorological phenomena.

But there appears to me to be good reason for believing that the influence of the solar activity upon our planet is of an even more profound and far-reaching nature than has hitherto been imagined. I shall endeavour here to state as briefly as possible the results of investigations (more fully developed in Astr. Nachr. No. 3619) which have led me to conclude that the period of solar activity can be distinctly traced in the minute residuals which it has not hitherto been possible to eliminate from the observed values of the earth's elements. We are thereby led to infer that the same unknown force which apparently plays so important a part in the meteorology of the sun, acts upon the motion of the earth to such a degree as to produce perturbations which, though minute, are yet of considerable importance from a theoretical and even practical point of view.

Now the question arises as to whether traces cannot be discovered of a similar influence upon the motion of the earth-spheroid synchronous with the eleven-years cycle of solar activity. The result obtained on this point receives additional importance from the fact that it throws quite a new light on the theory of a peculiar phenomenon, which has now greatly attracted the attention of astronomers, viz. the variation of latitude. The conclusion to be drawn from our investigation points to a close relationship between the amplitude of the motion of the terrestrial pole and the period of solar activity. It may be taken to be clearly established that the radius of the circle described by the pole of instantaneous rotation is greatest at times of sunspot-minima, and smallest at times of maximum-displays of solar spots. This correspondence is found to hold true for the whole interval of about sixty years now covered by Dr. Chandler's investigations. The subjoined diagram may help to give a clear idea of this peculiar relation, the first curve showing the semi-amplitudes of the latitude-variation for every year from 1856 to 1898, as deduced from Chandler's curves in Astron. Journ. Nos. 277 and 446, and from Dr. Nyren's values communicated in Publications de Observatoire Central Nicolas, Serie ii. vol. ii. ; while the second curve indicates the spot-frequency according to Wolf

during the same space of time. As the latitude-phenomenon has been found to lag behind the spot-curve by an interval of about 1. 5 years, the latter curve has been shifted one and a half years in the forward direction, in order to establish an agreement between the positions of the maxima and minima of the two curves.

Attention may here be drawn to Sir Norman Lockyer's discovery that a similar lag can be traced in the curves representing the changes in the lines widened in sun-spot spectra during a spot-cycle, the maxima and minima of the spectroscopic curves showing indeed, so far as observations go, a perfect synchronism with those of the curve of latitude-variation.

Judging from these curves the conclusion may be drawn that a very marked influence on the motion of the terrestrial pole of rotation is exerted by a force varying synchronously with the display of spots on the solar surface. Chandler's data previous to 1856 have not been included owing to their incompleteness. But it ought to be mentioned that the correspondence with regard to the positions of the maxima and minima is quite as certain as in the interval exhibited in the above curves. The sun-spot maximum in 1838 is followed by a minimum of the semi-amplitude in 1840, while the next sun-spot minimum in 1843 is succeeded by a very pronounced maximum of the semi-amplitude in 1845. Judging from the epochs of the maxima, the amplitude of the latitude variation completes three full periods in thirty-four years; while the epochs of the minima make this figure only slightly less, viz. thirty-two years. Hence the period of the amplitude is found to be eleven years.

On the whole, then, we are confronted by the fact, so distinctly brought out be observation, that the motion of our planet reveals traces of the action of a force, the intensity of which can be measured by the state of activity on the solar surface. No doubt, the perturbations caused by this force are extremely minute as compared with the gravitational effects exerted on the earth-spheroid. But still, in the present state of our theoretical knowledge regarding planetary motion, and with the high degree of perfection now attained in the art of astronomical observation, such minute quantities are of considerable importance. This is, for instance, sufficiently illustrated by the derivation of the solar parallax from the secular variations of the obliquity and the node of Venus. The value for this constant, as found after eliminating the perturbing effect of the new solar force from the secular variation of the obliquity, isir- 8". 802, a result which is in perfect accordance with Newcomb's value obtained from other sources. The great difficulty, by which this distinguished man of science found himself embarrassed in this part of his work (see pp. 158-159 of the treatise quoted above), so much so, indeed, that he well-nigh despaired of arriving at a final conclusion as to the value ofTT to be adopted, has now disappeared. The values for the masses of the earth, m(o"-*-f) 1:327923, as well as of Venus, m {&) 1:414991, as derived from the secular variations, may thus be accepted with confidence. This is one example showing the theoretical importance of the phenomena here discussed; possibly the results arrived at may be eventually found to contribute towards removing other difficulties still connected with the theory of planetary motions.

We are, it seems to me, fairly warranted in assuming the force acting in such a peculiar way on the motion of the terrestrial pole to be identical with that which exerts its influence on the secular variations. As regards the nature and origin of this force, there is a wide field for speculation. A suggestion to which I was led by a discussion on this subject with my colleague, Mr. G. Clark, of this observatory, and which seems worthy perhaps of further investigation, is that the force may stand in some connection with the still very mysterious phenomena of the earth's magnetism. There is certainly one fact

which lends some support to this hypothesis, viz. the eccentric position of the earth's magnetic poles. Joule's well-known experiments on magnetic strain in iron bars suggest the idea that something similar to the molecular displacement in the iron bar may take place in the body of the earth with regard to its magnetic axis. Such a strain along the axis of maximum magnetic moment would almost necessarily cause a displacement of the axis of figure with regard to the axis of rotation. Only so long as the total magnetic potential of the earth was not subject to alterations could this displacement remain constant. In that case the pole of rotation would describe a circle with a constant radius round the pole of figure. But there are facts which force us to assume that the potency of the earth's magnetic forces varies with the state of solar activity, and that consequently the molecular displacement in the direction of the magnetic axis varies accordingly. The most striking fact in this respect is the increase of aurorae with an increasing number of solar spots. Now, if we were to consider aurorae as discharges of electric force gradually accumulated in the earth's interior, the strain in the direction of the magnetic axis should have abated after such a discharge, and the pole of figure should therefore approach the pole of instantaneous rotation. This, then, would explain the fact that the semi-amplitude of latitude-variation is smallest after a maximum display of solar spots. How far this hypothesis is able to account for other phenomena brought out by observation must be left to future research.

GQS-005 LATITUDE-VARIATION, EARTH-MAGNETISM AND SOLAR ACTIVITY

Halm, J.; Nature, 62:460-463, September 6, 1900.

The significance of this paper lies in the possibility that solar activity may affect the earth's wobble, which now seems related to earthquake frequency.

In the Astronomische Nachrichten (No. 3619) I have published the results of an investigation dealing with the effects of periodic changes in solar activity on the motion of our planet. It is there shown that these changes, as indicated by the frequency of sun-spots, exert a subtle but pregnant influence on the secular variations of the earth's elements; and, moreover, that disturbances precisely similar to those which appear in the observations of the obliquity and of the sun's longitude are distinctly exhibited in the variation of terrestrial latitude.

In the further pursuit of these researches I have bean led to conclude that the anomalies existing in the observations of the sun's right-ascensions and declinations are to be attributed exclusively to changes in the position of the earth's axis of rotation with regard to the axis of maximum moment of inertia, and that these changes in their turn are intimately connected with the varying display of forces on the solar surface. In a subsequent article which appeared in Nature (No. 1584, March 8) I made a suggestion as to the nature of this connection, and advanced the hypothesis that the magnetism of the earth is probably the medium through which the changes of solar energy react upon the motion of the earth's pole.

There next follows extensive analysis of observations of the earth's motion, leading to the following:

The results of my researches may be thus shortly summarised:-

i. The changes in the motion of the pole of rotation round the pole of figure are in an intimate connection with the variations of the earth-magnetic forces.

ii. Inasmuch as the latter phenomena are in a close relation with the state of solar activity, the motion of the pole is also indirectly dependent on the dynamical changes taking place at the sun's surface.

iii. The distance between the instantaneous and mean poles decreases with increasing intensity of earth-magnetic disturbance.

iv. The length of the period of latitude-variation increases with increasing intensity of earth-magnetic disturbance.

v. In strict analogy with the phenomena of aurorae and of magnetic disturbance, the influence of the eleven-years period of sun-spots, as well as of the "great" period, is clearly exhibited in the phenomenon of latitude-variation; and the same deviations from the solar curve as are manifested by the aurorae are also evident in the motion of the pole.

vi. The half-yearly period of the earth-magnetic phenomena influences the motion of the pole of rotation in such a way that its path, instead of being circular, assumes the form of an ellipse, having the mean pole at its centre.

vii. The half-yearly period also explains the conspicuous fact of a rotation of the axes of the ellipse in a direction opposite to that of the motion of the pole.

GQS-006 THE FUTURE OF THE EARTH

Moreux, Abbe; Scientific American Supplement, 68:56-57, July 24, 1909.

Here follows an opinion of earthquake and volcano periodicity that was fairly typical early in this century. The electrostatic mechanism proposed is rather unusual however.

Earthquakes are more frequent in winter than in summer in the proportion of 3-1/2 to 1. They are also more frequent in the night and morning than at other hours. Atmospheric electricity follows the same law of periodicity that is observed in the case of earthquakes. Terrestrial electric and magnetic phenomena are governed by the sun and it seems probable that earthquakes and volcanic eruptions are similarly dependent on solar activity. Eruptions occur most frequently at intervals of eleven years, at epochs of minimum solar activity, which earthquakes occur chiefly at the epochs of most rapid increase and decrease of solar activity.

The explanation of the periodicity of earthquakes and eruptions is equivalent to the discovery of a periodic cause of contraction and expansion of the earth's crust. The variability of solar heat will not suffice, for we know that the temperature of the earth at depths greater than 50 feet remains constant. A more probable cause is found in the variable electric charge of the earth. It is a fact not generally known that the volume of a Leyden jar is increased by charging the jar and diminished by discharging it, wholly or partially. The crust of the earth resembles a Leyden jar, of which the coatings are represented by the liquid core and the enveloping atmosphere. The atmospheric charge and potential undergo diurnal fluctuations, falling during the night and early morning and attaining maximum values shortly after midday. We have seen that earthquakes occur chiefly during the night and morning, when the solar

radiation and electric charge are least and the contraction and internal pressure greatest. In the afternoon the increased charge causes a dilatation, as in the Leyden jar, the pressure is relieved.

GQS-007 THE DIURNAL PERIODICITY OF EARTHQUAKES

Davison, Charles; Journal of Geology, 42:449-468, July 1934.

Abstract. Though non-instrumental records of earthquakes give an apparent nocturnal maximum, it is shown that, for several regions in which earthquakes are weak or moderately strong, there is a real diurnal period, with its maximum about midnight. The instrumental records obtained in Japan and Italy and at various seismological observatories are examined, and it is shown that the maximum epoch of the diurnal period usually falls about noon or midnight, and that the noon maximum of the diurnal period is associated, as a rule, with a summer maximum of the annual period, and the midnight maximum of the former with a winter maximum of the latter. It is suggested that the noon and summer maxima occur in earthquakes caused by an elevation of the crust, and the midnight and winter maxima in those caused by a depression of the crust. It is noticed that the midnight and winter maxima prevail in regions in which the earthquakes are of slight or moderate intensity, and the noon and summer maxima in those visited by the most destructive shocks. In the after-shocks of great earthquakes, the maxima epoch are suddenly reversed, usually from near noon to near midnight, and the duration of the reversal varies from about a week to a year or more.

Conclusions. 1. Excluding after-shocks, the maximum epoch of the diurnal period is determined in 64 records. In 24 of these, it falls at or near midnight, in 35 at or near noon, and in 5 others at from 4 to 5-1/2 P. M. The average maxima for the first two groups are 0. 25 A. M. and 0. 40 P. M.

2. Of the 59 records in which the epoch falls near midnight or noon, the annual period is known in 37. When the epoch of the diurnal period falls near midnight, that of the annual period occurs in or near midwinter in 13 records and in or near midsummer in 5. When the epoch of the diurnal period falls near noon, that of the annual period occurs in or near midsummer in 16 records or in and near midwinter in 2. In one record, the epoch of the diurnal period falls at about 5-1/2 P. M. and that of the annual period at the end of May. Thus, in about 80 per cent of the records, the epochs of the diurnal and annual periods fall at noon and in summer, or at midnight and in winter. Of the other 7 exceptions, in one (Italy, 1891-1930) the diurnal epoch falls at 2 A. M. and the annual epoch in June; the others occur in records obtained at seismological observatories.

3. The opposed epochs of the diurnal period and the general relations between the diurnal and annual periods in regional earthquakes are probably connected with the directions of the crust displacements that cause the earthquakes. Let us suppose that an external force acts downward on the earth, such, for instance, as atmospheric pressure, with a diurnal maximum about midnight and an annual maximum in midwinter. Then, if the earthquakes were mainly due to a depression of the crust, the diurnal and annual seismic epochs would occur about midnight and midwinter. On the other hand, if the earthquakes were mainly due to an elevation of the crust, the epochs would occur about noon and midsummer. It is worthy of notice that the midnight and winter

maxima prevail in regions in which earthquakes are slight or of moderate intensity, and the noon and summer maxima in those visited by the most destructive shocks.

4. Assuming that a great earthquake is usually caused by an uplift of the crust, the displaced mass would at once begin to settle downward, and, during an interval that may last from a week to a year or more, the stronger after-shocks are caused by such downward slips. At the close of this interval, the forces that gave rise to the earthquake once more prevail, and further after-shocks, if they deserve that title, are due to the continued movements of elevation. It is interesting, however, to observe that, from the earliest days, after-shocks registered at any station may be caused by movements in both directions. For about 20 days after the Kwanto earthquake of 1923, the stronger after-shocks were due to subsidence, but they were accompanied by rather more numerous slighter shocks due to elevation. During the next 10 days, the stronger and more frequent after-shocks were due to elevation and the weaker shocks to subsidence.

GQS-008 THE ANIMUAI, PERIODICITY OF EARTHQUAKES

Davison, Charles; Seismological Society of America, Bulletin, 18:246-265, 1928.

Only the introduction and conclusions of this article are reproduced here. Of particular note is the association of earthquakes with the earth's wobble.

Introduction. The annual periodicity of earthquakes was discovered by Peter Merian, Professor of Physics and Chemistry in the University of Basel. In 1834, he published a small pamphlet on shocks felt in that city from 1020 to 1830. His list contains the dates of 122 earthquakes. For all but four of these the month was known, and it occurred to him to trace their distribution throughout the year. He found the following monthly numbers:

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
12	14	6	5	11	3	7	8	12	11	14	15

The preponderance during the winter months being evident, he next grouped them according to seasons with the following results: Winter (Dec.-Feb.), 41; spring (March-May), 22; summer (June-Aug.), 18; autumn (Sept.-Nov.), 37. Turning to other catalogues, Merian found the same winter preponderance in the earthquakes recorded in K. E. A. von Hoff's annual lists from 1821 to 1829, and, though less clearly, in those of L. Cotte's list for Northern Europe from 1775 to 1806.

Seven years later, Merian's discovery was confirmed by Alexis Perrey. In four early papers he noticed the same winter grouping of earthquakes, though, as he does not refer to Merian until the third paper, it is probable that his discovery was made independently. In the second of these papers, for the earthquakes of 306 to 1800, he gave the monthly numbers and summarized them thus: Winter (Jan.-March), 212; spring (April-June), 162; summer (July-Sept.), 148; and autumn (Oct.-Dec), 206. Later, in each of his twenty-one regional memoirs, Perrey studied the annual distribution of the earthquakes. Each monthly number was divided by the average of all twelve numbers, the results from different regions thus becoming comparable. For instance, the relative monthly numbers for the region consisting of France, Belgium, and Holland are

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1.52	1.17	0.97	1.01	0.77	0.66	0.86	0.73	0.91	0.88	1.09	1.43

or winter 1.22, spring 0.81, summer 0.84, and autumn 1.13. The curves illustrating the monthly variation were called by Perrey seismic curves.

Conclusions. 1. Ordinary earthquakes.——Throughout the vast continental areas of both hemispheres, the maximum spoch of the annual period in ordinary earthquakes falls during the mid-winter months. These great areas are, however, fringed by certain insular or peninsular regions in parts of which the maximum epoch is reversed. There is some reason for connecting such annual variation in seismic frequency with the annual variation in atmospheric pressure. The reversed epoch in insular districts is probably due, as Omori suggested, to the annual variation in the total pressure on the ocean bed.

2. Slightly destructive earthquakes.——Slightly destructive earthquakes, those of intensity 1 (Milne scale), are closely akin to ordinary earthquakes. They are, indeed, the limiting degree of such earthquakes. In all continental areas of either hemisphere, the maximum epochs of both fall in winter. And the same correspondence seems to hold for insular areas also. In the East Indies, ordinary earthquakes have their maximum epoch in May (amplitude 0.21), destructive earthquakes of intensity 1 in July-August (amplitude 0.24). Taking Japan as a whole, ordinary earthquakes have their maximum epoch in May (amplitude 0.08), destructive earthquakes of intensity 1 in December, with the rather large amplitude of 0.24. But, and this is a case of the exception proving the rule, 99 per cent of the earthquakes of intensity 1 originated in that part of Japan in which the maximum epoch of ordinary earthquakes occurs in winter.

3. Great destructive earthquakes.——Turning to the great destructive earthquakes, those of intensities 3 and 2 (Milne scale), the most striking fact is that their annual periodicity, in either hemisphere, is independent of geographical conditions. The maximum epoch occurs in the summer months, whether the regions are continental, peninsular, or insular. So clearly marked is this occurrence that it holds for such closely adjoining regions as the North and South Tropical Zones. In Japan, it falls throughout in the summer months; in the southwestern portion, in which the epoch for ordinary earthquakes falls in winter, the maximum is in July, with the rather high amplitude of 0.25; in the northeastern portion, it is probably in May or June (amplitude 0.38), but the number of earthquakes is too small to define the epoch with accuracy.

It would seem, then, that destructive earthquakes of great intensity differ entirely in their origin from those of less strength and from ordinary earthquakes. And, in this connection, it is worthy of notice that many destructive earthquakes of the first magnitude originate at depths that may be perceptible fractions of the earth's radius, and that the relation that Milne detected between the occurrence of great earthquakes and the displacements of the pole holds, as Omori has shown, for a strong, but not for slight, earthquakes in Japan.

GQS-009 THE INNER HARMONY OF THE WORLD

Hasbrouck, L. M.; American Mercury, 91:81-87, December 1960.

This article is astrological in tone. The author makes predictions and these are compared with events in later issues. A few excerpts will demonstrate his method, which is evidently based on planetary positions. Note that the same approach has

been used by legitimate scientists to correlate short-wave propagation (Subsection GET), weather patterns (Subsection GWS), and earthquakes (Subsection GQS).

There is nothing strange or occult about these forecasts. They violate no law of science, old or new. The forecast dates are calculated through the timing of natural changes of potential in the field of the earth, by means of the harmonics of the solar system. These field changes are found to induce field-force disturbances which—as Mercury readers have seen—coincide with a variety of observable phenomena, including earthquakes of 6 magnitude and over.

The implication behind the consistent accuracy of these forecasts is that they can serve to restore to modern thinking the long lost concept of a natural, universal law, functioning in orderly rhythms behind all the phenomena of life and human perception.

Earthquakes were selected for this presentation as being one of the most tangible factors in our long record of forecasting field-force disturbances. This record began in 1940 relative to radio interference and has since developed to include other phenomena, whose number continues to grow. In 1960, a new area of possible correlation has shown itself. We observed that a number of the failures in missile launching tests coincided with dates of field-force disturbance previously listed in our forecasts.

Mercury readers are aware that our forecasting of field-force disturbances involves this ionospheric area. The results so far obtained have shown two factors not yet achieved, or even recognized, by geophysicists. One is that these disturbances can be timed long in advance of their arrival; they can be predicted. The other is the implication as to the source of the disturbances, i.e., the field——the unified field of the solar system of which the earth is an integral part.

There is no mystery, today, about the field. To the physicist, it is "as real as the chair on which he sits, " even though it is, at the same time, "like the atom, a mental construct, the product of idea into experience." Nor should there be any mystery about the timing of those field-force disturbances which coincide, 90 per cent of the time, with radio blackouts and or major earthquakes. The cosmic clock of the solar system has been working accurately since long before man's comprehension caught up with it. The solar system is "the model for all scientific mechanism . . . timeless, unchanging, fixed in the eternal scheme of things. " The only mystery is that science has not learned how to use the mechanism of the solar system in the art of forecasting.

Only the concept of a unified field can account for the fact that these timing signals coincide with such a wide variety of physical phenomena; earthquakes, volcanic eruptions, radio blackouts, and even such events as the much publicized breakdown of New York's Consolidated Edison power circuits on August 17th, the day of the great Yellowstone earthquake which coincided with one of our forecast signals. (See Mercury. January 1960.) And now comes the intriguing possibility of a further, practical link with the problems of space travel——an area which of course calls for extensive, high level research, but which might result in saving billions of dollars for the American taxpayer.

GQS-010 SOLAR, LUNAR, AND PLANETARY EFFECTS

GQS-010 PERIODICITY OF VOLCANIC ERUPTIONS AND EARTHQUAKES

Anonymous; Nature, 66:353, August 7, 1902.

Circular No. 49 of the Wolsingham Observations contains a summary, by the Rev. T. E. Espin, of the results obtained by arranging and charting the data which he has collected in regard to the times of volcanic eruptions and earthquakes.

These results point to a period of between eight and nine years in the phenomena of which Mr. Espin has received the records.

This period agrees with the period of revolution of the moon's perigee, and further investigation indicates that the greatest volcanic activity takes place when the perigee occurs at its maximum northerly declination.

GQS-011 GRAVITY WAVES MAY SET EARTH RINGING

Anonymous; Nature, 230:208, March 26, 1971.

Searching for confirmatory evidence of Weber's gravity waves is becoming a fashionable exercise. In next Monday's Nature Physical Science, V. S. Tuman of Stanislaus State College, California, puts forward, in a tentative manner, the notion that excitation of the Earth by gravity waves may be the explanation of some anomalous results obtained with gravity meters. Tuman has already described in Nature a cryogenic gravity meter developed in co-operation with Stanford University to record the oscillations of the Earth (229, 618; 1971), but the anomalous effect has also been noticed in records taken elsewhere. What it amounts to, in brief, is that as a rule the even harmonics of the eigen vibrations of the Earth detected by the gravity meters contain more energy than the odd harmonics.

Tuman points out that the existence of the effect is not definite, however. But two series of observations out of three carried out with the cryogenic gravity meter show the discrepancy in energy content between the odd and even harmonics, and the effect is also present in results reported by Block et al. (Nature, 226, 343; 1970). One explanation considered and then discarded by Tuman is that the oscillations in question are excited by earthquakes occurring at locations which ensure that the gravity meter at Stanislaus College is always at a node corresponding to no motion for the odd harmonics and a finite motion for the even harmonics.

This could be the explanation if the earthquakes exciting the vibrations were at an angular distance from the gravity meter of fairly precisely 90°. But the explanation fails to work if the earthquake is more than a few degrees off this orientation. With earthquakes at least of Richter magnitude 5.5 being necessary to generate detectable oscillations, and for other reasons, this mechanism is not particularly convincing.

Tuman suggests therefore that the anomalous distribution of energy might have an explanation from outside the Earth, in gravity waves of high energy density. Such a gravity wave pulse would be expected to couple energy into the „S2„ modes and their overtones with quadrupole moments, leaving the odd spheroidal modes („S2n+1) unaffected. The evidence for this mechanism is still far from convincing, however, but Tuman points out that a network of similar gravity meters would help to solve the problem.

SECTION GS: SOUND PHENOMENA

With so many jets aloft and the other sounds of modern technology, man can conveniently ascribe anything he hears to one machine or another. Nevertheless, concealed in the noisy background there are many detonations, hums, swishes, and even musical sounds that are not man-made. These are divided into the following categories.

GSD Strange detonations. Explosive sounds, apparently from nowhere, often localized and with long histories. Examples: the Barisal Guns, the Seneca Guns, the Lough Neagh waterguns, etc. Correlation with earthquakes, meteors, whirlwinds, and other phenomena.

***GSG** Infrasonic sound. Association with storms and auroras. Physiological effects.

GSH Hums, hisses, etc. Unexplained hums heard in many localities. The Yellowstone Lake "whispers," brontophonic sounds, and so on. Correlation with meteors and auroras. Possible effects of electromagnetic waves on human perception.

GSM Music, bells, etc. Odd oceanic sounds, Bell of Nakous, Cry of Memnon, etc.

***This subsection not represented in Volume G2.**

GSD-046 [POLTERGEIST NOISES]

Fort, Charles; The Books of Charles Fort, Henry Holt and Company, New York,
I 1941.

The following account is added here to illustrate a possible connection between apparent physiological responses to geophysical phenomena and paraphysical events. Detonations, it appears, are rather common in poltergeist reports.

> In the New York Tribune, Jan. 7, 1900, there is an account of poltergeist disturbance in a house, in Hyde Park, Chicago. According to the now well-known ways of chairs and tables, at times, these things hopped about, or moved with more dignity. It was as if into the house stole an invisible but futile assassin. See back to accounts of visible but futile bullets. Time after time there was a sound like the discharge of a revolver. It was noted that this firing always occurred "at about the height of a man's shoulder." In a booklet, A Disturbed House and its Relief, Ada M. Sharpe tells of a seeming psychic bombardment of her home in Tackley, Oxen, England. Beginning upon April 24, 1905, and continuing three years, at times, detonations, as if of exploding bombs, were heard in this house. Upon the 1st of May, 1911 (Lloyd's Weekly News, July 30; Wandsworth Borough News, July 21) unaccountable fires broke out in the house of Mr. J. A. Harvey, 356 York-road, Wandsworth, London. Preceding one of these fires, there were three explosions of unknown origin. In January, 1892 (Peterborough Advertiser, Jan. 10, 1892) a house in Peterborough, England, occupied by a family named Rimes, was repeatedly shaken, as if bombed, and as if bombed futilely. Nobody was injured, and there was no damage, (p. 943)

There may be no connection, but ball lightning often explodes inside houses and often without damage to people or things.

GSD-047 REPORT UPON THE EARTHQUAKE OF OCTOBER 31,1895

Marvin, C. F.; Monthly Weather Review, 23:374-375, October 1895.

Prof. Cleveland Abbe, editor of the Monthly Weather Review, is the source of the following comment on seismic noises.

> "Small cracks, with attendant shocks, are continually occurring everywhere throughout the globe. Some localities are famous for mysterious noises that have almost in every case been traced to the cracking of rocks near the surface. Such are the famous Moodus noises at the town of that name in Middlesex County, Conn., where the Salmon River empties into the Connecticut River. Such sounds are heard at the famous gneiss quarries of Monson, Hampdon County, Mass.; whenever a large piece of rock is loosened, loud crackling noises are produced. On the slopes of Black Mountain, N. C., in 1876, many mysterious noises were heard, until, finally, it was discovered that a large portion of rock was cracking and settling."

GSD-048 STRANGE DETONATIONS

GSD-048 SEISMIC AND OCEANIC NOISES

Kain, Samuel W., et at; Monthly Weather Review, 26:152-154, April 1898.

(A) Mr. Samuel W. Kain, in his letter of April 27, 1898, says:

It give me much pleasure to send you by this mail a copy of Professor Ganong's article. I am also sending you two short notes from lighthouse keepers at the mouth of the Bay of Fundy. Mr. McLaughlin is at the southern end of Grand Manan; Mr. Suthern is on Brier Island, on the Nova Scotian shore.

I wrote to these men in order to get some more information about this phenomenon. I have also personally questioned masters of fishing schooners, all of whom are familiar with these sounds, and among whom they are known by the somewhat vulgar but very expressive name of "sea farts." I am sending you these papers because I think these sounds very similar to those discussed in Europe about two years ago by Van den Broeck, Darwin, and others. A reference to them in the Review may elicit more information than we now have.

(B) Walter B. McLaughlin, of Grand Manan, on remarkable sounds like gun reports, etc. (read March 1, 1898, before the Natural History Society of New Brunswick, and now quoted from the St. Croix Courier):

I beg to say that my attention was first called to these sounds in August, 1838. I was then a boy nine years old. I was with my brother and a fine young sailor, by the name of McCraw, of Lower Grandville, N. S. We were hooking mackerel, and I had just caught my first mackerel when "boom" went this heavy sound and away went our fine school of fish. McCraw said, "There she goes." I inquired the cause of these sounds so frequently made and the sailor's answer was: "We don't know, we hear them, but we can't explain them."

I have no doubt that many sounds heard by people on the main land are actually reports of Indians' guns in porpoise hunting, or the reports of our signal guns on those outer stations, but a practised man will not be deceived. I have noticed these sounds for fifty-nine years. I long since satisfied myself that these sounds are subterranean. I have heard them under the sea, under Gannet Rock, under the land (in South Lubec), and under Grand Manan in two different places; and, strange to say, we have had two splendid shots under this station lately, one on the evening of January 28 and the second on February 14, 1897. When they take place under Gannet Rock and under the land they have the heavy rattle of a 24-pounder cannon, exploded 40 feet from the buildings; but when they happen under the sea they have a dull harmless "boom," as such a gun would sound if fired 50 or more fathoms under the sea.

We used to hear those dull sounds frequently between the Wood Islands and Gannet Rock. They would often sound like the rush of a heavy ground swell into a subterranean cave. We always noticed them on fine calm days. I think this was because there was no wind or other noise to drown them. The first one of those sounds I heard under Gannet Rock was about fifty years ago, one clear, dark night, about 2 o'clock a. m., in my watch. I was reading and was deeply interested, when bang went the shock of what seemed to be like a 24-pounder cannon. It brought down the soot from a heavy, boiler iron, extension pipe on the chimney top into an open fireplace. I, of course, went outside to investigate and found a clear, dark night with few clouds and light winds, It was, I think, in October.

My next experience of one of those sharp shocks was in the month of June, 1856, at South Lubec, West Quoddy Bay. I was at a Dr. William Small's, and was having a game at cards with the doctor about 2 o'clock in the morning, when bang went one of those subterranean guns, which nearly upset our lamp. I ex-

claimed, "An earthquake!" but the doctor said, "No; it's an airquake, " an explanation I never heard before nor since till I read it in the bulletin of the Natural History Society.

My third experience of those shocks on solid ground was at Seal Cove about eight years ago, say at 11 o'clock in the evening, when the shock was exactly as the former ones, the night being quiet and dark with very light winds. Again on the 28th of January of this year (1897) at 9 o'clock in the evening we got such a shock under this lighthouse that we thought the tops of our chimneys had gone by the board. Our dogs took to barking and our cattle tried to break loose in the stable. I noted this shock in my journal and told my people that we would hear of an earthquake on the mainland, but when the mail came we found that the earthquake was two days ahead of our tremor. On the evening of February 14, at 9 p.m., we received another shock, but not so violent as that of January.

I have given you my experience of fifty-nine years, and I will now affirm that I strongly believe these sounds are of subterranean origin.

(C) E. W. Suthern, from a letter to Mr. Kain, dated April 15, 1898, at Westport Light, Brier Island, Digby County, N. S.:

I have noticed these sounds many times when I have been out on the Bay of Fundy on fine, calm days in the summer. I spend a good deal of time in this way, shooting porpoises and birds. The sounds heard in this place are like the distant firing of heavy guns. I have heard these sounds on all sides of my boat, and that is what has puzzled me. I have heard them between my boat and the shore when one-half mile off shore, and again I have heard them in the same direction, ten miles off. I have also heard them in a southwesterly direction, and there is no land within 300 miles wouthwest of here, and I know that the Indians are not shooting porpoises in that direction.

In my opinion these sounds are not the firing of guns; they are heard only in calm, warm weather, and never in the nighttime or in the winter. I have asked the fishermen about them and they say that they hear these sounds on all sides of them.

(D) W. F. Ganong, of Smith College, Northampton, Mass., on remarkable sounds, like gun reports, heard upon the southern coast of New Brunswick (dated December 24, 1896, Bulletin XIV of the Natural History Society of New Brunswick):

Everybody who has been much upon our Charlotte County coast must remember that upon the still summer days, when the heat hovers upon the ocean, what seem to be gun or even cannon reports are heard at intervals coming from seaward. The residents always say, in answer to one's question: "Indians shooting porpoise off Grand Manan. " This explanation I never believed; the sound of a gun report could not come so far, and, besides, the noise is of too deep and booming a character. I have often puzzled over the matter, and it is consequently with great pleasure that I find in Nature for October 31, 1895, a short article by Prof. G. H. Darwin, in which he calls attention to the occurrence of what is obviously the same phenomenon in the delta of the Ganges, upon the coast of Belgium, and in parts of Scotland, and in which he asks for experiences from other parts of the world. Two explanations are suggested by his correspondent, M. Van den Broeck, of Belgium, who called his attention to the phenomenon, one that the reports are of atmospheric origin, due to peculiar electrical discharges; the other that they are internal in the earth, due, perhaps, to shock of the internal liquid mass against the solid crust. The following number of Nature contains notes which suggest that the reports may accompany the formation of faults or may result from earthquakes too slight to be otherwise perceived, and later numbers of that journal contain numerous letters upon strange sounds heard in different parts of the world, with various explanations.

GSD-048 STRANGE DETONATIONS

The discussion upon the subject by this society on December 3, 1895, has called out further information showing that others besides myself have noticed these or similar sounds in New Brunswick. The late Edward Jack, a keen observer of things in nature, wrote me under date December 13, 1895, "I have often noticed in Passamaquoddy Bay, when I was duck shooting in the early spring mornings, the noises of which you speak; they always seemed to come from the south side of the bay. They resembled more the resonance from the falling of some heavy body into the water than that of the firing of a gun, such as is produced by a cake of ice breaking away from a large sheet of it and toppling over into the sea. These noises were heard by me only in very calm spring mornings when there was no breath of air; * * * there was nothing subterranean in them. " Capt. Charles Bishop, of the schooner Susie Prescott, has told Mr. S. W. Kain that he has heard these sounds 40 miles from land between Grand Manan, the Georges Banks, and Mount Desert Rock. They are reported also from the Kennebecasis. Mr. Keith A. Barber, of Torryburn Cove, wrote December 26, 1895, to this society: "I have heard sounds similar to those on the Kennebecasis in the warm days of summer. They seemed to come from a southeasterly direction.'' Mr. Arthur Lordly, a member of this society who resides in the summer at Riverside, has also told Mr. Kain that he has heard similar sounds, on clear warm days, on the Kennebecasis, from a southwest direction. No other reports of this occurrence in New Brunswick have reached me. The Scientific American (June 27, 1896, p. 403) has called attention to them and requested that observations be communicated to its columns, but apparently so far without result.

The latest opinion as to the origin of sounds appears to favor an atmospheric origin, possibly connected with electrical disturbances. A very detailed circular, calling for exact observations, with series of questions and blank forms has been the first to call scientific attention to them. It is very desirable, since the sounds occur here, that they should be scientifically observed and recorded; and it will be best to communicate the results to this society, through which they will reach those who can make the best use of them. To secure the best results the following form, altered somewhat from M. Van den Broeck's circular, should be followed:

Name of observer.
Date of observation.
Exact place of observation.
Exact time of each observation.
Direction of the sound.
Character of the sound (full description with comparisons).
Wind direction and velocity.
State of the sky.
State of the sea.
Mist conditions.
Barometer (state of the weather a few hours before and after).
Temperature.
Other remarks, including suggestions as to their origin, and reasons why they can not be gun reports.

(E) Although the above-described sounds have generally been attributed to some form of disturbance with the earth, the noise from which comes up through the ocean, and although they are, therefore, called seismic noises, yet it is by no means certain that they may not have a very different origin and it would be more proper to call them oceanic noises. The descriptions given of these oceanic noises show that sometimes they have precisely the same characteristics as the noises that may be heard in an aquarium when one stands alongside

of a big glass tank and watches the motions of the drum fish. The salt water drum fish (Pogonias Chromis) is common on the Atlantic Coast of the United States, and other varieties will doubtless be found in other parts of the world. A large drum fish will give out a sound that may be heard a long distance. As the sound is refracted into a nearly horizontal direction on its emergence from a level surface of water, it may seem to come from a great distance in the air when it really is near at hand in the water underneath or near to a fisherman's boat. If there are other fishes of great size that can give forth louder sounds, having different notes, we should not be surprised at the variety of descriptions of the various mysterious sounds. But at present these oceanic noises defy all attempts at rational explanation; we must wait until accurate observations have been collected.

As these sounds appear to be very frequent on fine, calm summer days in the Bay of Fundy, it seems practicable to start a special investigation of the subject in that neighborhood. The actual direction whence a sound comes that originates under water can best be studied by means of a pair of tubes whose lower ends are closed by metal or preferably glass plates. The upper end of the tube being open and in open air while the lower end is immersed several feet under water and pointed successively in different directions, we have only to ascertain the direction for which the sound that enters the tube is strongest in order to know the direction whence it comes. The use of this tube avoids the error incident to the refraction of the sounds as they emerge from the surface of the water. —Ed.

(F) Through the kindness of Prof. Alexander Agassiz, the Editor has been favored with the following note, under date of May 23, 1898, from Dr. S. Garman, Icthyologist to the Museum of Comparative Zoology at Cambridge, Mass.:

The list of noisy fishes is an extensive one; it runs through the Scioenoids, Cottoids, Batrachoids, Cyprinoids, Siluroids, Gymnodonts, and others. Most of them are small and their voices are not loud. Myliobatis, Aetobatis, and Rhinoptera, among the rays, are said to make a noise by grinding their teeth when caught; it may be they also do it when feeding. But the fishes that will best answer the queries of your correspondent are the large Scioenidoe, many of them probably more or less noisy. In their cases the dates of hearing the sounds should be noted. The large "drum," Pogonias, attains a length of more than 4 feet. The following from page 118 of Holbrook's Ichthyology of South Carolina, 1860, relates to it: "At this time [April] the drum enters the different bays and inlets of salt water along the shores of South Carolina to deposit its spawn, and then begins its drumming noise; this season passed, the sound is no longer heard, and the fish is then rarely taken.

"The way in which the singular sound called drumming is produced has not hitherto been satisfactorily explained. Cuvier observes that it may depend upon the air bladder, though he says it has no communication with the external atmosphere. DeKay supposes it 'to be occasioned by the strong compression of the expanded pharynegeal teeth upon each other. '

"Frequent examinations of the structure and arrangement of the air bladder, as well as observations on the living animal just taken from the water, when the sound is at intervals still continued, satisfied me that it is made in the air bladder itself; that the vibrations are produced by the air being forced by strong muscular contractions through a narrow opening, from one large cavity, that of the air bladder, to another, that of the cavity of the lateral horn; and if the hands be placed on the side of the animal, vibrations will be felt in the lateral horn corresponding with each sound.

'Ichthyologists differ also as to the character of the sound. Schoepff speaks of it as a 'hollow, rumbling sound under water;' Dr. Mitchill, as a 'drumming noise;' Dr. DeKay says when the fish is 'freshly taken from the water it sounds as if two stones were rubbed together.' It resembles most the tap of a drum, and is so loud that when multitudes of them are collected together it can be heard in still weather 'several hundred yards from the water. "'

The drum of which Holbrook writes is Pogonias cromis Linne, 1766.

(G) Note by Prof. A. E. Verrill, of Yale University, New Haven, Conn, (dated May 31, 1898):

There are numerous fishes, both marine and fresh water, that are capable of making sounds of considerable volume under water. Such fish noises might very well account for many instances of the noises referred to. The drum fishes, the "grunts," are good "examples of sound-producing fishes. "

(H) To the preceding note by Dr. Garman the editor would add the suggestion that the intensity and character of the sound, as heard in the air, will depend somewhat upon the relation between the depth of the fish in the water and the pitch of the note uttered by it.

Just as the vibrating column of air in an organ reed pipe produces the greatest effect when it is in perfect unison with the vibrating tongue at the base, so it is with the column of water above the drum fish. An open organ pipe that is controlled by a spring or reed that vibrates to the lowest C of the bass clef, namely, thirty-two times per second, must have a length of 16 feet. The same pipe, if filled with fresh water, may be longer in the ratio 4708/1093, viz, the ratio between the velocity of sound in air and water. This gives a depth of about 70 feet at which the drum fish that strikes the bass C could produce the maximum noise as heard by the observer. If, now, the bottom of the water is 70 feet below the fish then he is at a nodal point, and the whole column vibrates in sympathy with him.—Ed.

(I) Prof. William F. Ganong writes from Northampton, Mass., as follows, May 31, 1898:

I can not in the least accept your suggestion about the drum fish. It is true I have never heard this animal perform, but the sounds come from too far off and are too great to be made by a fish. On hills a quarter of a mile from the sea I have heard them, and the sound filled the air. Your mode of investigating them by the tubes would be difficult in practice, since the sounds come so rarely; days will pass without our hearing them, and even on favorable days they occur only once in a while, perhaps once in a day, but at the best they occur several hours apart as a rule; in fact, they may be described as rare and irregular. Hence, one would have to be on constant guard at the tube for hours and even days together. Mr. McLaughlin, of Document B, is a man for whose powers of observation and reliability I have the greatest respect, and his letter is, therefore, an important contribution to this subject.

(J) Instead of accepting any hypothetical explanation as satisfactory, it is best, at the present stage of the investigation, to keep one's mind free from prejudice in any special direction. It seems quite possible that the noises proceeding from the ocean may have very different characters and origins; some are undoubtedly due to the drum fish; others are made by the breakers dashing on rocky cliffs, whence heavy thuds spread for several miles through the air and many miles farther through the ocean; others are due to the cracking of rocks in ledges near the surface, such as those on which lighthouses are built; others, finally, are occasionally due to genuine earthquakes occurring at the

bottom of the neighboring ocean. It is highly probable that a careful collation of observations from many stations in any given locality, such as the Bay of Fundy, will throw a clear light upon the locality whence the noises emanate.

In this connection it is worth calling to mind that there are eight or ten well-defined regions on the North American Continent within each of which there is a so-called center of seismic disturbance. There is no reason why similar centers should not exist under the ocean; in fact, the great solitary waves that have been frequently reported by vessels between New York and Newfoundland, and which have generally been plausibly explained as due to a combination of several ordinary waves, may sometimes be due to suboceanic earthquakes, just as similar great waves are known to have been produced by earthquakes in the Pacific.—Ed.

Note that the Barisal Guns are frequently heard in multiples——twos and threes-whereas the noises in the Bay of Fundy are single and widely spaced. A common denominator with the Barisal Guns and mistpouffers is their preference for fine, calm weather.

GSD-049 [MISTPOUFFERS IN THE PHILIPPINES]

Anonymous; Nature, 85:451, February 2, 1911.

The Rev. M. Saderra Maso, who has for many years studied the earthquakes of the Philippine Islands, is now turning his attention to the subterranean noises known in other countries under various names, such as mistpoeffeurs, marinas, brontidi, retumbos, &c. In the Philippines many terms are used, generally signifying merely rumbling or noise, while a few indicate that the noises are supposed to proceed from the sea or from mountains or clouds. Most of the places where they are observed lie along the coasts of inter-island seas or on enclosed bays; very few are situated on the open coast. The noises are heard most frequently at nightfall, during the night and in the early morning, especially in the hot months of March, April, and May, though in the towns of the Pangasinan province they are confined almost entirely to the rainy season. They are compared in 70 per cent, of the records to thunder. With rare exceptions, they seem to come from the mountains inland. The instances in which the noises show any connection with earthquakes are few, and observers usually distinguish between them and the low rumblings which occasionally precede earthquakes. It is a common opinion among the Filipinos that the noises are the effect of waves breaking on the beach or into caverns, and that they are intimately connected with changes in the weather, generally with impending typhoons. Father Saderra Maso is inclined to agree with this view in certain cases. The typhoons in the Philippines sometimes cause very heavy swells, which are propagated more than a thousand kilometres, and hence arrive days before the wind acquires any appreciable force. He suggests that special atmospheric conditions may be responsible for the great distances to which the sounds are heard, and that their apparent inland origin may be due to reflection, possibly from the cumulus clouds which crown the neighbouring mountains, while the direct sound-waves are shut off by walls of vegetation or inequalities in the ground.

GSD-050 STRANGE DETONATIONS

GSD-050 BARISAL GUNS IN AUSTRALIA

Cleland, J. Burton; Nature, 81:127, July 29, 1909.

In Nature of June 4, 1908 (vol. Ixxviii., p. 101), under the title of "Barisal Guns in Western Australia, " you published a note from me describing a peculiar, loud detonation heard by my companions and myself while on the Strelley River, in the north-west of Australia. [See GSD-002] In reading Captain Sturt's "Two Expeditions into the Interior of Southern Australia during the Years 1828, 1829, 1830, and 1831, " I find that, when camped on the newly discovered Darling River, near what is now the town of Bourke, in New South Wales, in February, 1829, a very similar sound was heard by the explorers. Sturt's words are as follows:- "About 3 p. m. on the 7th Mr. Hume and I were occupied tracing the chart upon the ground. The day had been remarkably fine, not a cloud was there in the heavens, nor a breath of air to be felt. On a sudden we heard what seemed to be the report of a gun fired at the distance of between five and six miles. It was not the hollow sound of an earthly explosion, or the sharp cracking noise of falling timber, but in every way resembled a discharge of a heavy piece of ordnance. On this all were agreed, but no one was certain whence the sound proceeded. Both Mr. Hume and myself had been too attentive to our occupation to form a satisfactory opinion; but we both thought it came from the N. W. I sent one of the men immediately up a tree, but he could observe nothing unusual. The country around him appeared to be equally flat on all sides, and to be thickly wooded: whatever occasioned the report, it made a strong impression on all of us; and to this day, the singularity of such a sound, in such a situation, is a matter of mystery to me" (2nd edition, 1834, vol. i. , p. 98).

GSD-051 STRANGE NOISES IN HAITI

Anonymous; Literary Digest, 46:396, February 22, 1913.

A summary of Scherer's report [GSD-008],

GSD-052 AIR QUAKES

Clark, Joseph; English Mechanic, 82:433, December 15, 1905.

I have been interested in what I have read at page 401, "Scientific News, " concerning what Mr. H. G. Fordham calls an "air quake," as it goes to explain what was heard here a few minutes past 3 p. m. on Nov. 18——namely, what was taken for thunder. From what I have ascertained from people who heard it the sound was as loud as thunder, but not exactly like thunder. It consisted of three reports——one loud, the next very loud, and the last more like a reverberation. People sitting indoors heard it as well as those out, and it was heard in a straight line at places three to four miles apart——from Ashcot in N. W. to Outleigh Wooton, S. E.——but I have not heard of anyone hearing it either N. or S. of the S. E. to N. E. line. Street is lat. 50° 7', long. 2° 44*.

Here, again, we have triplets of detonations.

GSH-014 NORWEGIAN TESTIMONY TO THE AURORAL-SOUND

Tromholt, Sophus; Nature, 32:499-500, September 24, 1885.

How widespread in our days is the belief in the sound of the Aurora in Norway, the following may show: In March, 1885, I despatched some thousand circulars to all parts of the country containing different queries regarding the aurora, and amongst these also the following:——Have you or your acquaintances ever heard any sound during aurora, and, in this case, when and in what manner? Up to this date I have received answers to these queries from 144 persons in different parts of the country. Of these there are not less than 92, or 64 per cent, who believe in the existence of the aurora-sound, and 53 (36 per cent) of these again state they have heard it themselves, whilst the other 39 cite testimonials from other people; only 21 (15 per cent) declare they never have heard the sound or know anything about it, and the other 31 (22 per cent) have not noticed the query at all. There are thus 92 affirmations against 21 negations.

Only a few of the very large number of descriptions are reproduced here.

The sound is described in these answers in the following manner:-

Sizzling (3)
Creaking or sizzling
An intermediate sound between sizzling and whizzing, sometimes as if a piece of paper were torn
A kind of sound as when you tear silk
Soft whizzing, alternative with sizzling
Soft crackling, sizzling
Hissing and crackling
Whispering and glistering
A rather heavy rush, as from a distant waterfall
Quiet whizzing, hissing
Hissing, or hoy! hoy! hoy!
Whiz (2)
Rush, as from a stream
Soft but distant crackling, as from a lighted match-cord
Whizzing (5)
Rush, as when sheep are chased
Soft hissing, soft whiz
Whizzing or whistling
Crackling (4)
Hissing
Crack in the air
Din in the air
Continuous sounding, rolling din in the air
Clashing
Flapping, as a flag before the wind
Partly as rustling or flapping of sails hanging loose fore the wind, partly as hissing from fire
Monotonous whizzing and creaking, as when a sheet flaps before the wind
As from a feeble burning flame
Like burning dried juniper
Cutting, hissing as from flames
Crackling and creaking, a noise as from a large fire-flame——as, for instance, burning dried boughs
Like the sound from a flight of birds
Strong flapping noise, as when a bird passes very near you
Crackling from fire and flapping from wings
As of a bird flying through the air with great velocity
Like the buzzing of a bee
Roaring noise, as when strong gushes of wind dart through the tree tops of the wood
Creaking sound as from the blowing of the wind
Distant roar, as from a storm
Roaring as from a storm
Roaring as from a whirlwind
Like the soft breeze through a wood
Whipping with whisk-brooms
Soft noise, as when fanning with a piece of paper from a distance
Soft flapping with a piece of cloth
Roaring of the sea

GSH-015 HUMS, HISSES, ETC.

Like the noise from a distant, before the wind-flapping flag, which now and then sends out a creaking sound

Heavy, hollow roar from the sea
Sweeping sound, as when dry snow is sweeping over an ice-field

GSH-015 SOUND OF THE AURORA

Ogle, John **W.** ; Nature, **24:5,** May **5, 1881.**

The interesting communications which have lately appeared in your periodical regarding the supposed connection between "sound" and the "aurora" (Nature, vol. xxiii, pp. **484, 529, 556),** lead me to suppose that the following notes may be considered by you and your readers worthy of record. They were copied last autumn by myself from the Strangers' or Visitors' Book at the Hotel on the Aeggischorn, and bore the date July **10, 1863:-**

"Visit to the Col de la Jungfrau described: On descent surrounded by thunderclouds evidently charged with electricity. At **12.15** a sound similar to that made by a boiling kettle was heard to issue from one of the alpenstocks, and very soon a similar sound issued from all the batons. On shaking the hands similar sounds issued from the fingers. Observing that the veil of one of the party stood upright on his hat, one of the gentlemen and one of the guides, who had experienced prickly sensations on the crown of the head, removed their hats, when their hair stood up as if under a powerful electrical machine. Whenever there was a peal of thunder all of the phenomena ceased, to be speedily renewed when the peal was over. At such times all the members of the party felt severe shocks in the parts of the body which were most affected; and one gentleman had his right arm paralysed and rendered useless for several minutes. The clouds-passed away and the phenomena finally ceased at **12.30.** The guides with us were Joseph Marie Claret of Chamouni, and Smith of this house, and they were as much affected by the electricity as we were. At the top of the Col the aneroid barometer stood at 18. 83."

These mountain-top effects are far from uncommon, but this article suggests that the vibratory noises may be akin to the supposed auroral noise.

GSH-016 SOUND OF THE AURORA

Constable, F. C. ; Nature, 24:53, May 19, 1881.

In Nature, vol. xxiii, p. 484, one of your correspondents speaks of the sound of the aurora as "crackling, " or as that of "the flickering of blazing fire, " while another describes it as like the "rustling or switching of silk. " On Monday, April 12 last, there was an electric storm here, and at 7 p.m. when I walked home (the blazing lightning leaving but momentary intervals of darkness), I heard all round me the constant crackling or rustling of blazing flames. Towards the north-west across a low arc near the horizon pale sheet lightning swayed quickly to and fro. There was no rain at the time, that came heavily afterwards. The sound of flames was close round me, and others had the same experience. No one I can find has ever seen lightning so completely fill the air or heard such strange sounds.

The implication here is that the auroral sound may originate in nearby electric discharges.

GSM-006 [THE CRY OF MEMNON]

Gould, Rupert T. ; Enigmas, University Books, New Hyde Park, 1965.

The colossal statue of Memnon, situated among the ruins of Thebes, was erected about 1500 B. C. and has at various periods in history been the source of strange sounds.

> "Still from his chair of porphyry gaunt Memnon strains his lidless eyes
> Across the empty land, and cries each yellow morning unto thee. "

If Tennyson, as seems likely, excelled Wilde as a poet, he nevertheless showed himself inferior to the author of The Sphinx when he wrote:

> ". . . . from her lips, as morn from Memnon, drew
> Rivers of melodies."

The sounds which are recorded as having been emitted by the famous "vocal statue of Memnon" were neither many nor melodious. Infrequently, but always at sunrise, those who stood near it long ago might hear a thin, strident sound, like the breaking of a harp string. That was all—an aimless cry heard at rare intervals during a relatively short period of two hundred years, a period preceded and followed by many centuries of silence. Yet it was a phenomenon of which hardly any similar case is on record—and it was not, it should seem, a deception. The statue, which had been silent so long, and again has sunk into silence, did once acquire the exercise some strange inherent power of saluting the sun. (p. 26)

GSM-007 NOISES AT SEA OFF GREYTOWN

Oliver, S. P. ; Nature, 4:26-27, May 11, 1871.

In Nature, vol. ii. p. 25 [GSM-001] Mr. Dennehy gave an interesting account of a peculiar vibration, accompanied by sound, which is perceivable at night on board all (?) iron steamers which anchor off Greytown, Central America; and in subsequent pages I have read with great interest various speculations as to its origin, which is ascribed (1, the probable solution) to troops of Sciaenoids (with reservation) by Mr, Kingsley (p. 46); (2) to musical fish or shells, by Messrs. Evans and Lindsay (pp. 46 and 356); and (3) to gas-escape from vegetable mud and sand, by Mr. Malet (p. 47); whilst Mr. Dennehy himself suggests the possibility of some galvanic agency.

I remarked upon this vibratory phenomenon in a communication published in the Field newspaper of October 26th, 1867, signed "Ubique, " after having heard it myself when on board the Royal Mail steamer Danube (Capt. Reeks) during the nights of the 12th, 13th, 14th, and 15th of May, 1867; the new moon occurring on the 4th of the same month. As my statement serves to confirm Mr. Dennehy's report, I may be forgiven for giving it in full.

After giving an account of the sudden appearance of a huge white shark in the deep sea when a man fell overboard, I proceeded to state as follows:——"On embarking on board the Danube steamer, lying at anchor in the roadstead off Greytown on the 12th May, 1867, I was informed that the ship was haunted by most curious noises at night since she had arrived, and that the superstitious black sailors were much frightened at what they thought must be a ghost. The

captain and officers could make nothing of it, and it afforded a great matter for discussion. On inquiry I found out that other iron ships had been similarly affected. Curiously enough this noise was only heard at night, and at certain hours. Some attributed it to fish, suckers, turtle, &c., others to the change of tide or current; but no satisfactory conclusion could be arrived at. When night came on there was no mistake about the noise; it was quite loud enough to awaken me, and could be heard distinctly all over the ship. It was not dissimilar to the high monotone of an Aeolian harp, and the noise was evidently caused by the vibration of the plates of the iron hull, which could be sensibly perceived to vibrate. What caused this peculiar vibration? Not the change of current and tide, because, if so, it would be heard by day. Like everything else that we cannot explain, I suppose we must put it down to electricity, magnetism, &c. If this should meet the eye of any of the officers of the above-mentioned steamer, or others who have noticed this phenomenon, I should be glad to hear whether this effect still continues, or if any satisfactory conclusion has yet been arrived at. I may add that from the hold of the vessel the grunts of the toadfish could be distinctly heard. I hope that the above notice may lead to some answers from your various correspondents."

This brief notice drew forth a rejoinder from a correspondent (November 23, 1867) who had noticed a somewhat similar sound.

"The singular sound noticed by 'Ubique,' I have also heard without knowing its origin. One moonlight night in 1854, on board a steamer anchored near the Tavoy river (Tenasserim) we were struck by an extraordinary noise which appeared to proceed from the shore about a quarter of a mile off, or from the water in that direction. It was something like the sound of a stocking loom, but shriller, and lasted perhaps five or six seconds, producing a sensible concussion on the ear like the piercing scream of the cicada; and this gave an impression as if the vessel itself were trembling, or reverberating from the sound. One or two Burmans on board said simply, the noise was produced by 'fishes,' but of what kind they did not describe. It was repeated two or three times. I never heard it before or after the occasion referred to, nor have I ever met with any allusion to this singular phenomenon until I perused 'Ubique's' communication in the Field of the 26th ult. The steamer in my case, I should add, was a wooden one. "

Mr. Evans, in his letter, speaks of the rapid silting up of Greytown harbour this still continues, and the passage over the bar, which is continually shifting, if often a matter of great difficulty, and indeed often so dangerous that the Royal Mail Company will not undertake to allow their own boats to land, and passengers have to land in the local canoes at their own risk. The Nicaraguan Government, however, propose to carry out Mr. Shepherd's plan of diverting the waters of the San Juan river from the Colorado mouth to the Greytown channel, hoping thereby to scour the harbour clear.

Mr. F. J. Evans also refers to the vast amount of animal life, and mentions the quantities of sharks and alligators which abound in and about Greytown Harbour. I can fully corroborate this, although I believe that what Mr. Evans terms alligators are really crocodiles (Molina Americana), I should be glad to have certain information on this point: when not actually visible, their proximity is made evident by a powerful odour of musk. The most notable, however, of the denizens of these waters, besides the turtle, is the Atlantic manatee, which Columbus mistook for a mermaid, and which Agassiz terms the modern representative of the Dinotherium. The Mosquito Indians on the Indian, Rama, and Blewfields rivers are great adepts at harpooning this paradozical mammal, and its flesh salted is a staple article of food all along these coasts, being not unlike to ship's pork.

SECTION GV: VOLCANIC PHENOMENA

In this section, emphasis is on thermally caused phenomena. Volcanoes, of course, are the principal creators of such effects, but wherever hot magma is near the surface strange effects are often noted. The fumeroles and mudpots of Yellowstone are prosaic examples. In these sourcebooks, only the more unusual volcanic phenomena will be recounted.

GVS Solar, lunar, and planetary correlations.

***GVT** Geothermal phenomena. Local "hot spots" with unusual side effects or possessing strange properties.

GVV Volcanic phenomena. "Strange phenomena" associated with volcanoes and not specifically covered in other sections, such as the generation of volcanic electricity and peculiar ejecta.

•This subsection not represented in Volume G2.

GVS-001 VOLCANOES AND THE SUN AND MOON

Still, Elmer G.; Scientific American, 86:433, June 21, 1902.

Kindly permit me to call your attention to some remarkable coincidences between certain positions of the moon, relative to the earth and sun, and the recent earthquake and volcanic disturbances. Do not the following comparisons of facts go to prove that such disturbances are most likely to take place when the moon is directly in line with the earth and sun (conjunction, opposition, eclipse), when the moon is nearest the earth (perigee), and when it crosses the earth's equator?

The moon crossed the earth's equator on April 19; the terrible earthquakes in Guatemala began on the evening before and continued until the 21st. The moon was full and at eclipse node on April 22; the volcanoes in the West Indies first showed signs of activity on the day following. The moon crossed the equator again on May 3-—the day that Mont Pelee, on the island of Martinique, first began eruption. The moon was new and at eclipse node on May 7 and in perigee on the 8th; La Souffriere volcano, on the island of St. Vincent, began violent eruption on May 7, and Mont Pelee destroyed the city of St. Pierre on the 8th. Then, as the moon receded from perigee, getting farther away from the earth, the volcanoes gradually quieted down until the activity ceased on May 15. The moon crossed the equator again on Friday evening, May 16, and on Friday Mont Pelee again began eruption, which became violent next day.

The writer has for several years been observing this relation between the positions of the heavenly bodies and seismic, volcanic, and electrical disturbances, and is forced to the conclusion that the latter are caused in part by the conjunctions, oppositions, perihelions (or perigees) and equinoxes of the moon, earth, and seven other planets, especially when several of these occur at once. Such disturbances do not always occur at these times, but observation proves that nearly all of them do so occur. It is not claimed that the relative position of the heavenly bodies is the sole cause; it is only an aggravating cause and must be combined with local causes and conditions in order to produce seismic and volcanic disturbances. Scientists now recognize the fact that sun spots are caused by the perihelion, etc., of Jupiter and other large planets. Then why are not earthquakes caused in the same general manner?

The writer is convinced that severe disturbances of these kinds can be predicted as accurately as the weather, and that the recent volcanic outbreak could have been predicted with a certainty several days in advance, and the awful loss of life thus averted. The writer felt certain that there would be another severe volcanic eruption on May 16 and 17, and it came.

The moon will cross the earth's equator again on May 31 and June 13, will be in perigee on June 5 and new on June 6; therefore, more volcanic and seismic disturbances are probable on and about those dates in various parts of the world, but especially where they have been occurring recently.

I submit these facts and theories for your candid and unbiased consideration, and in conclusion I earnestly request that you express your opinion of them in the Scientific American, or at least explain them to your readers, so that these facts and theories may be carefully investigated by scientists for the benefit of mankind.

GVS-002 VOLCANOES AND THE SUN AND MOON

Still, Elmer G,; Scientific American, 87:54, July 26, 1902.

Referring to your comments on my communication about "Volcanoes and the Sun and Moon," published on June 21, you have apparently misunderstood my theory, as I do not maintain that volcanic and seismic action should be greatest where the tide is highest and least where it is lowest. The abnormally high tide in the Bay of Fundy is evidently caused by the "contour of the continents," as you state, for the moon's attraction is of course no greater at the Bay of Fundy than elsewhere in the same latitude, and therefore volcanic and seismic action is not expected to be greatest there.

The influence of the moon and planets in causing and intensifying seismic and volcanic disturbances is not altogether tidal action——gravitational; it is partly, or mostly, electrical, and seismic and volcanic action is an electrical disturbance. This is the reason why sultry weather, which always accompanies thunderstorms, also goes with volcanic eruptions and often with earthquakes. Hence, sultry weather is popularly called "earthquake weather," and in the Hawaiian Islands it is known as "volcano weather." It is a remarkable fact that "when Mont Pelee blew up, magnetic needles two and three thousand miles away quivered on their pivots."

The effect of the moon's crossing the earth's equator is electrical disturbance, not at all gravitational, and a little observation and reading of the daily papers will prove that electrical storms, and in fact severe storms of all kinds, are more frequent at about the time of the moon's equatorial passage than at any other time. In proof of this, note the terrific storms that occurred about May 3, 16, 31 and June 13 and 27, even in this country alone, and also notice what occurs on and touching the following moon-on-the-equator dates the rest of this year: July 10, 24; August 6, 21; September 3, 17, 30; October 15, 27; November 11,23; December 8, 21. Some interesting experiments by Prof. Elmer Gates on "The Electrical Causes of Changes in the Weather" were described in the Scientific American of August 10, 1901.

I cannot agree with you that a relation must be established between planetary positions and "moments of volcanic outbreaks or severe earthquakes," for the planetary cause is not the sole cause (as it is with tides); in some cases where a volcano is almost strong enough to burst forth of its own accord, the planetary influence is strong enough to precipitate the outbreak a good many hours, or perhaps a whole day, before the actual moment of the conjunction, perigee, etc.; the planetary influence comes on gradually and is cumulative, my observations indicating that volcanic and seismic disturbances are more likely to occur shortly after rather than before, or at the moment of, the planetary positions.

Following are some more "coincidences:"

The volcano of Kilauea, in the Hawaiian Islands, began eruption on July 4, 1901——the day before the opposition of Saturn——and continued through the moon's equatorial passage on the 6th, perigee on the 11th, and new on the 15, ceasing about 30 hours after the moon crossed the equator again on July 19.

An Associated Press dispatch of April 17 stated that Albrim, Lopevie and Tingoa volcanoes, in the New Hebrides Islands, were in eruption on March 10—— another moon-on-the-equator date.

In Alaska, Mount Blackburn erupted on April 11——the next day after perigee——and Mount Redoubt on May 3——the same day that Mont Pelee began eruption——caused by the moon on the equator.

A dispatch states that the seismographs of W. A. Eddy, the Bayonne (N. J.) seismologist, recorded earth tremors from the east-southeast on the night of May 15-16, leading him to predict new eruptions in the West Indies, and that "this is the first motion of the seismograph needles since March 22." On referring to my almanac 1 find: moon on equator May 16 and March 23; also full 23d; perigee and equinox, 21st.

Some coincidences omitted from my first letter were the perihelion of

Mercury on May 4, with the first eruption of La Soufriere next day, and the occultation (direct conjunction) of Mars by the moon on May 7, when that volcano was at its worst.

The predictions in my communication of May 18 were verified by the eruption of Mont Pelee on May 30, earthquakes in Hawaii on May 31, two eruptions of Kilauea June 1, a "violent outburst" of Mont Pelee June 6, and again on the night of June 13-14.

If scientists will not admit any influence of planetary conditions in causing seismic and volcanic disturbances, they must then account for simultaneous disturbances of this kind in different parts of the world by supposing that distant volcanoes are connected, and that, therefore, a large part of the interior of the earth is molten matter——which they cannot deny must be subject to the same gravitational influence that causes the tides.

GVS-003 GRAVITATION AS A CAUSE OF VOLCANIC ACTION

Still, Elmer G.; Scientific American, 87:203, September 27, 1902.

Your correspondent in the issue of August 9, writing on "Gravitation as a Cause of Volcanic Action," evidently doubts that certain planetary positions cause electrical disturbances in the earth, and that volcanic and seismic action may be caused by electrical or magnetic influences. But let us consider carefully the evidence in favor of these propositions.

We know that magnetic earth currents (which interfere with telegraphing), brilliant auroras, severe thunderstorms, violent storms of many kinds, and also earthquakes and volcanic activity accompany sun spots. All these are electrical disturbances, and the eruption of Mount Vesuvius and numerous seismic shocks which occurred at the time of the last large sun spots—about September 15, 1898——were no doubt electrically caused by them.

The moon's equatorial passage has certainly no gravitational influence, and yet it must be something more than mere coincidence that severe volcanic and seismic disturbances have accompanied this planetary position every time during the past four months, with but one exception: None were reported for June 27; but the abnormally severe storms on and about that date proved the electrical effect. The moon's last equatorial passage, on August 21, caused terrific earthquakes in Mindanao, Philippine Islands, and a violent eruption of Mont Pelee on that date, more shocks at Los Alamos, Cal., on August 20, 21 and 22, earth-tremors for two hours in Austria and violent tremors near St. Petersburg on the 22d, and an eruption of Mount Allomonte, Italy, beginning the same day. All these were two to four days after full moon and half-way between apogee and perigee.

Within twenty-four hours of the direct opposition of Saturn on July 17, there were terrific tremors on St. Vincent Island, cloudbursts in Illinois, a tornado in Ontario, and a typhoon at Hongkong——all electrical disturbances.

The recent severe earthquakes at Los Alamos, Cal., began a few hours after the very close conjunction of Mars and Neptune on July 27, and were most

severe on that night and on the 31st, when Mercury was again in perihelion, and the day before perigee.

Mercury is found to have more influence in causing seismic and volcanic action than almost any other planet—probably because of its eccentric orbit, nearness to the sun, and frequent periods. About fifteen hours before the superior conjunction of Mercury on August 11 at 4 a. m., there was a severe earthquake and tidal wave at Juneau, Alaska, and there were frequent shocks at Los Alamos from 4 p. m., August 9, to 12 p. m. on the 12th, the most severe one occurring at 2:40 p.m. on the 10th. Mercury's equinox of August 27 probably caused the eruption of Mont Pelee on the afternoon before.

All the other earthquakes and volcanic eruptions reported in the newspapers during July and August, with but two exceptions, came just as expected according to this astronomic theory. Among these were the violent eruption of Mont Pelee on the evening of July 9——described and illustrated in the Scientific American of August 16——and also those on the 10th and morning of the 11th, the moon crossing the equator on July 10.

As to the electrical disturbances that accompany volcanic eruptions being "caused by the heat from the volcano"——as your correspondent maintains——that is, of course, partly true; and this electrical energy might also "touch off other volcanoes; for I have certainly not altogether mistaken effect for cause, and these remarkable and constantly-recurring coincidences furnish a good proof that seismic and volcanic action may be electrically caused and that certain planetary positions, such as close conjunctions and oppositions, equinoxes, perihelions and perigees, cause electrical disturbances in the earth and also, probably, throughout the solar system.

Similar effects would probably result when several planets come directly into line with each other or with the sun, although not in line with the earth, and also if most or nearly all of the twenty other satellites should cross their primaries' equators at nearly the same time. Planetary positions of this kind must have occurred on May 20 and August 14.

The best way, it would seem, to prove and perfect this astronomic theory of volcanic action would be to compare the times of greater and less activity in some perpetually active volcano, like Stromboli, in the Mediterranean, or Sangay or Cotopaxi, in Ecuador, with the prevailing planetary positions. Here is a suggestion for the "international convention of scientists for the study of seismological problems," which—according to an Associated Press dispatch——Emperor William of Germany is endeavoring to bring about for next spring.

Just how certain planetary positions cause electrical disturbances in the solar system or disturb the electrical equilibrium is a subject for theorizing and investigation: but however difficult it may be to understand does not disprove the idea in the face of the evidence. There are many things we cannot explain the whys and wherefores of, such as the X-rays, wireless telegraphy, telepathy, clairvoyance, etc., but that should not prevent us from believing in and making use of these principles of nature. The scientific investigator must seek simply the truth, without bias or prejudice, no matter if reasons are not apparent.

The most probable dates in the coming two months for seismic and volcanic disturbances to begin or to reach a maximum are September 1, 3, 11, 17, 22, 23, 30; October 1, 10, 15, 16, 19, 23, 27 and 30.

The ideas of Still should be compared with those expressed in GMS, GQS, GWS, and the series E sourcebooks. Still is very confident of his thesis, but the statistics are tricky. Furthermore, with nine planets and the moon, alignments and special configurations are rather common.

GVV-001 THE RECENT EXTRAORDINARY SUNRISES AND SUNSETS

Noble, William; Knowledge, 5:418, June 6, 1884.

The importance of this article resides in the observation that brilliant sunrises and sunsets were seen before the eruption of Krakatoa. Much was made during the years following Krakatoa about how it was the cause of the unusual atmospheric phenomena. Could Krakatoa have been merely coincidental (and late at that), or were other agencies involved?

It is pretty well known that a committee has been appointed by the Royal Society to (ostensibly) investigate the cause of those remarkable sunrises and sunsets which, during the latter half of the past, and the earlier portion of the present year, have attracted attention throughout the civilised world. As a matter of fact, this said committee was established to prove that the wonderful fore and after glows had their origin in the eruption of the Javan volcano Krakatoa, on Aug. 27, 1883; and as it would be worse than useless to send such evidence as I subjoin to this nice, impartial little association, I forward it to Knowledge instead. At all events, it will not be burked there. It is contained in a letter from Mr. E. Neison, F. R. A. S., F. C. S., &c., the Director of the Government Observatory at Natal (so well known as the author of our classical work on "The Moon"), and only reached me yesterday morning:-

"In England," says Mr. Neison, "you seem all busy over discussing the extraordinary sunsets. They began in Natal in February, 1883, but on a less grand scale, but gradually became more marked until June. Then for two months nothing was noticed. In the latter end of August they became most vivid. On the 21st and 22nd they were noticeable, but not vivid. The next five days were stormy, with much rain and lightning. On the 28th and 29th the sunsets were most vivid. The 30th was rainy. August 31 and September 1, 2, 3, and 5 were fine, and the vivid redness of the sky was most remarkable, fading away as it did into green and purple in the east. Then came a week of much rain, and the sunsets vanished, not to return for nearly four months, except in a very faint degree. In February and March of this year they again became very noticeable, but did not last so long. Now (April 2) they have gone again. Now for a remarkable point. In the Transvaal they were first noticed in the beginning of September——the 2nd, I think——and were most vivid until the end of January, though here, only some 250 miles off, nothing was seen. They disappeared, as far as I can gather, from the Transvaal in January. . . . . I am inclined to believe the sunsets to have been purely meteorological. Those in February, 1883, were sufficiently marked to induce me to try a water-colour sketch on February 8. It was spoilt next day by two visitors to the observatory who upset a glass of water over it, smashing the glass and making general havoc. I got a specimen of the fine dust which fell on the ships in the Indian Ocean some days after the eruption of Krakatoa. It was absolutely free from any metallic iron or mineral containing iron decomposed by hydrochloric acid——pumice-stone pure and simple, I believe. I tested it expressly for iron in both these forms. It was a very fine greyish-white dust. "

So, here was the Government Astronomer at Natal actually drawing one of these marvellous sunsets between six and seven months before there was any eruption of Krakatoa whatever. The italics in the quotation above are Mr. Neison's, not mine.

GVV-002 VOLCANIC PHENOMENA

GVV-002 KILAUEA VOLCANO, HAWAII: A SEARCH FOR THE VOLCANO-MAGNETIC EFFECT

Davis, Paul M., et al; Science, 180:73-74, April 6, 1973.

Compiler's Summary: The investigators hoped to show that magnetic anomalies preceded volcanic eruptions and might, therefore, have predictive value. Previous measurements around New Zealand volcanoes had encouraged this hope. This paper reports measurements made in the vicinity of Kilauea Volcano, Hawaii. During twelve months of observations, only a slight correlation between magnetic anomalies and ground tilt were observed, leading to the conclusion that no large-scale pattern of stresses could be supposed, which would, in turn, give rise to a piezomagnetic effect. The Hawaiian volcano might also be structurally different from those studied in New Zealand.

GVV-003 [GELATIN-LIKE MATERIAL FROM VOLCANO?]

Anonymous; Nature, 25:492, March 23, 1882.

> The volcanic phenomena which have lately alarmed the inhabitants of the Aetolian coast have not yet ceased. There is now no doubt that a submarine crater has been formed. A short time ago a tolerably violent shock of earthquake was felt, accompanied by subterranean roaring and hissing. At the same time a strong odour of sulphuretted hydrogen rose from the sea. A thick layer of a gelatine-like mineral matter covers the surface of the sea to a great distance, and floats upon it like a layer of oil. It is not disturbed by the sea being in a high state of agitation, but has, on the contrary, a tranquillising effect upon the motion of the waves.

GVV-004 WATER AND THE GENERATION OF VOLCANIC ELECTRICITY

Blanchard, Duncan C, and Bjornsson, Sveinbjorn; Monthly Weather Review, 95:895-899, December 1967.

Abstract. Electrical measurements, made both in the laboratory and at Surtsey volcano, have indicated that highly charged clouds are generated when water comes into contact with molten lava. An examination of the literature has revealed a number of cases where electrical activity in volcanic clouds appeared to be caused by this process. The significance of this charge generation mechanism, as opposed to others that undoubtedly operate in volcanic eruptions, remains to be established.

The effect described in this paper is, of course, the basis for volcano lightning.

SECTION GW: WEATHER PHENOMENA

Weather is so incredibly varied and possesses so many facets that the following list must be considered preliminary only.

GWC Strange clouds. Noisy clouds, clouds pulsing with light. Luminous and strange-shaped clouds. Correlations with earthquakes, meteors, and other geophysical phenomena.

GWD Dark days. New England's famous dark day and the many similar instances. Some are explained in terms of forest fires, but others are associated with earthquakes and other events.

***GWF** Peculiar fogs. Fogs and mists that are sometimes correlated with earthquakes, auroras, and light wheels. "Blasting" fogs.

GWP Precipitation oddities. Colored rain, snow, and hail. "Blood" rain.

Unusual hailstones. Point rainfall and cloudbursts. Giant snowflakes.

***GWR** Temperature anomalies. Sudden drastic changes in temperature.

GWS Solar, lunar, and planetary correlations.

GWT Tornadoes and waterspouts. Unusual behavior. Correlations with ball lightning, luminous columns, unusual sounds, burning effects, and physiological effects.

GWW Whirlwinds and dust devils. "Pranks" of whirlwinds. Possible electric and magnetic effects.

•This subsection not represented in Volume G2.

GWC-001 A CASE OF SLOW, SUB-TROPICAL DISCHARGE OF EARTH ELECTRICITY, AND THE SUN RECOGNISANT THEREOF

Smyth, Piazzi; Nature, 24:212-213, July 7, 1881.

In the course of yesterday afternoon, in the midst of a sky otherwise clear and exquisitely blue, a large cloud of unusual shape and character began to form in the upper regions of the atmosphere vertically over, but very far above, the southern slope and even most elevated mountain tops of Madeira, and remaining there, as it did, most fixedly more than half the day, so contrary to the locomotive habits of ordinary clouds, it seen attracted the attention, and presently the fears, of most of the inhabitants.

As seen from this place, between 1 h. and 3 h. p. m., there was little more than a single dense cloud of peculiarly rounded outline and somewhat elliptical figure, stretching from the western horizon to within 10° or 15 of the zenith; but as time advanced, other and successively smaller clouds were formed directly under the first, having symmetrical and concentric outlines therewith, while the central vertical axis, which might be conceived as passing through the whole series, remained unchanged and fixed in space. This central fixity, too, of them all continued, together with the infinite smoothness of the outlines of all the smaller lower strata of cloud, although the largest and uppermost one visible to us began to put forth a variety of fringes of cirro-cumulous character; and, as tested by the spectroscope before sunset, all the lower smooth-rimmed clouds were remarkable for the large quantity of watery vapour they contained, and held fast too, for no rain fell. As sunset approached every one was gazing at the strange phenomenon of a cloud-congeries of most portentous size and absolute fixature above the trade-wind, probably also the anti-trade region; and after sunset the most gorgeous coloured illuminations through all the ranges of scarlet-red, red, crimson-red, ultra-red, and then dun-coloured and grey passed from member to member of the series, distinguishing the various heights of its strata one above the other; while the greatness of the general height was shown, even long after darkness had set in, by a faint lunar-like illumination of the northern outline of the whole. But by ten o'clock that began to fail, and the system of superposed clouds was beginning to contract on its central axis, and faded away, without leaving its place, before morning.

Smyth goes on at length to inquire whether the cloud might not be due to electrical discharge from the mountain peaks stimulated by high solar activity. See his subsequent letter which follows. The date of the event described above was June 26, 1881.

GWC-002 THAT MADEIRA EARTH-ELECTRIC CLOUD AGAIN

Smyth, Piazzi; Nature, 24:530-531, October 6, 1881.

Well, do you remember my letter to you from Madeira on June 27 (Nature, vol. xxiv. p. 212 [GWC-001], with a sequence on p. 237) describing the extraordinary cloud that appeared there on June 26, alarming all the inhabitants, the typically "oldest" of whom declared they had never seen such a cloud as that before? It was, too, in very truth a most remarkable affair; and seemed to me only to admit of full explanation as a peculiar case of the earth answering by escape of its interior electricity to the sun; where, according to my own daily

solar diagrams, there had just occurred an outburst of solar spots very nearly over the ends of the solar radii that were then pointing towards the earth.

Weeks passed on without anything to interfere with, or under-value, that explanation; when lo! on July 26 (the very same day, curiously enough, of the next month) another cloud appeared over Madeira, of just the same peculiar physical character as that of June 26. "Why," were inclined many visitors to ask, "is the kind of cloud, in spite of the asseverations of the 'oldest' inhabitants, no very great rarity after all in this part of the world?" There had been certainly thus two cases of it occurring with a very short interval between them; but nevertheless, I was inclined to respect that assertions of the greybeards; and said, "Something unusual must again have happened in the sun; but as my observatory was dismantled on July 23, and the component parts of it packed up ready for shipment on July 25 and 26, I had not then any knowledge of what it might be." Now, however, see how perfectly Mr. Hennessey's Indian solar photographs fulfil all that was required to make this second Madeira cloud phenomenon an exactly similar cosmical case to that of its mensual predecessor; or to testify that an extraordinary unusual, most sudden outbreak of solar spots did take place over the very part of the sun's surface turned towards the earth late on July 25, and within twenty-four hours afterwards the earth-electric cloud made its appearance above Madeira, where it was thus noted in my pocket journal

"Tuesday, July 26.——During this afternoon there was a great cloud-structure formed to the west, with all the characteristics of smooth-rimmed lenticular strata under strata, and the topmost visible one breaking out into fringes of cirro-cumuli, that marked the still grander cloud of June 26."

More speculation follows.

GWC-003 ELECTRICAL CLOUD PHENOMENON

Burton, W. K.; Nature, 41:10, November 7, 1889.

A short description of a curious cloud appearance observed by me this summer may be of interest to your readers. It was noticed in Kiushu, the southernmost of the three great islands of Japan, early in July, at a distance of ten or twelve miles from the sea.

The season had been, and was, after the time of the observation, an exceptionally rainy one, severe floods being produced in almost all parts of the country, but it was not raining in the place where I made the observation at that particular time. Time shortly after midday, thermometer about 80°F.

The sky was clear overhead, but there was a great bank of heavy "thunder ous" looking clouds to the south. It is most difficult to judge even approximately of the distance of clouds, but these might be from one to two miles off; the lower edge was represented by a very nearly straight line, and there was an amount of blue sky visible under the clouds that would perhaps subtend from 10° to 15°.

My attention was attracted to a sort of "tail" of cloud stretching itself downwards from the straight underside of the cloud-bank. It gradually extended till it reached some two-thirds of the distance from the cloud to the earth. It remained of about constant length for a little over ten minutes, the lower end continually waving about in a most curious way, giving the impression almost that it was feeling for something.

Quite suddenly the filament of cloud straightened itself out, and extended itself towards the earth. The lower end became so very thin that, from the distance, it was impossible to see whether it actually made contact with the earth or not, but I have not the smallest doubt that it did, and that a silent discharge took place at the time. There was certainly no sound heard. Immediately after the contact the filament rapidly drew itself up to the cloud, and was incorporated with it. Almost immediately after this, whether as a mere coincidence or not I cannot tell, the cloud discharged a great amount of rain.

P. S.——The appearance was not unlike the illustrations of "water-spouts" that I have seen, but there was no whirling motion such as is always described as accompanying these, nor, indeed, was there any evidence of violent disturbance of any kind at all.

This observation might be classified under "pranks of clouds" to correlate it with "pranks" of lightning, tornadoes, etc.

GWC-004 [RATTLING CLOUD]

Anonymous; Pursuit, 2:32, April 1969.

Jacksonville Beach, Florida (AP)——Hundreds of persons——including Police Chief James Alford——reported strange sounds coming from two clouds. Ojie man described the sound as like "someone rattling cellophane." A woman said it was more like "someone walking on pebbles." Alford ordered Capt. Harold Bryan to follow the first cloud. Bryan did so——to the edge of the Atlantic where the cloud dissipated. The listeners started to go back inside their homes when, they said, another cloud repeated the performance. Bryan also followed it to dissipation over the Atlantic. Officials at the Mayport Naval Air Station said they could offer no explanation; neither could other officials.

GWC-005 [CRACKLING CLOUDS]

Anonymous; Chicago Daily News, February 10, 1969. (As quoted in INFO Journal, 1:30-31, Spring 1969.)

Miami (AP)——Flapping, crinkling, crackling clouds were reported over Miami Sunday.

"It sounds like a big bird flapping its wings and trying to get off the ground, " said William Bard.

"No, it's more like huge sheets, of wax paper being crumpled, " said his wife Charlene.

The clouds were reported over Jacksonville, last week, but no one there could explain the sounds. Neither could the U. S. Weather Bureau in Miami.

GWC-006 STRANGE CLOUDS

GWC-006 RUMBLING CLOUDS AND LUMINOUS CLOUDS

Zeleny, John; Science, 75:80-81, January 15, 1932.

A brief description of two rather unusual cloud phenomena which have come to my notice may be of some interest. One of these was observed from the east shore of a narrow bay of Cache Lake in Algonquin Park, Ontario, on an early morning during the latter part of July of this year. It was a chilly morning and the sky was completely overcase with clouds. My attention was attracted by a rumbling sound coming from the west, such as heralds the approach of a heavy thunder storm. As I watched, a very long, low, narrow, tenuous cloud, resembling a squall cloud, appeared above the trees on the opposite shore, moving at right angles to its length. The continuous, rumbling noise, now grown remarkably loud, seemed to come unmistakably from this cloud, whose cross-sectional diameter was only about 200 feet. The cloud passed overhead eastward and was not followed by the expected rain storm. The cloud apparently marked the meeting place of two oppositely directed currents of air that differed in temperature. It seems almost incredible, however, that so much sound could have arisen from the agitated air alone, and yet this seems to be the only plausible explanation of its origin. I steadfastly looked for small lightning flashes in the cloud and saw none, although they would have had to come in rapid succession to produce the persistent sound which was heard. The noise could not have come from the rattle of hail because the cross-section of the cloud was too small to give time for hail formation; and in any case no hail fell.

The other cloud I wish to describe was a solitary, brightly luminous, cumulus cloud which I saw on a clear summer night at Hutchinson, Minnesota, some thirty-five years ago. The cloud had a horizontal diameter of about a third of a mile and a thickness of about one fourth of that distance. It rose majestically from the eastern horizon, shone with a uniform, steady, vivid, whitish light and passed directly over the town. When the cloud was overhead a great shower of insects descended to earth covering the ground all around to the number of about 50 to 100 per square foot. These insects proved to be a species of hemiptera and were non-luminous. They had apparently been induced to take wing by the bright object in the sky. I have been at some loss to account for the luminosity of the cloud. It could not have been due to reflected light coming from a city. It might be postulated that the cloud consisted of a mass of organic vapor that was slowly oxidizing, being in fact a.case of an extended will-o'-the-wisp, but for several reasons this seems to be an unlikely hypothesis. At the time the cloud was observed, it was thought to be far too late in the evening for its light to be reflected sunlight. There is a possibility that a bright moon below the horizon might have been the source of the light, although I have no recollection of having seen the moon rise later.

GWC-007 WHIRLING WHAT-IS-IT?

Anonymous; Life, 35:208, December 7, 1953.

Compiler's Summary: A lenticular cloud over a peak in Java is described. The cloud suddenly began to rotate at a high speed. No further information given.

GWD-001 HISTORICAL SUN-DARKENINGS

Hind, J. R.; Nature, 20:189, June 26, 1879.

Not a few persons appear to have been much exercised by a prognostication emanating from an American source, whereby the public are forewarned of an approaching period of sun-darkening to extend over several days. History does record instances in which the sun has been abnormally obscured or its light paled to such an extent that stars have come into view in the daytime, and Erman, Humboldt, and other writers have brought these occasions into prominent notice, the former in connection with the presumed passage of dense meteoric streams between the earth and the sun. The earliest mention of such a phenomenon appears to be in the year B. C. 44, about the time of the death of Julius Caesar, when we read in Plutarch and Dio Cassius that the sun was paler than usual for a whole year, and gave less heat, the air continuing cold and misty. The darkness for two hours on August 22, A. D. 358, appears to have preceded the great earthquake of Nicomedia. Two years later in all the eastern provinces of the Roman Empire we are told there was "caligo a primo aurorae exortu adusque meridiem," and the stars were seen, the further description being rather applicable to a total solar eclipse; but neither the eclipse of March 4, 360, nor that of August 28, would be visible in those parts. Again, when Alaric appeared before Rome, the darkness was such that stars were seen in the daytime (Schnurrer, "Chronik der Seuchen"). Following the Tablettes Chronologiques of the Abbe Lenglet Dufresnoy, Alaric invested Rome A. D. 409, and became master of the city on August 24, 410; there was a visible eclipse of the sun on June 18 of the latter year, therefore while the siege was in progress; but on calculating the circumstances under which it would be seen at Rome, introducing the latest lunar elements, it appears that little more than half the sun's disk would be covered at the greatest phase about 2h. 40m. p.m., and no sensible diminution of sun-light would be occasioned by the eclipse. In 536, 567, and 626 we find mention of long periods of diminished sun-light. Schnurrer records that in 733, a year after the Saracens had been driven back beyond the Pyrenees, consequent on their defeat at Tours, "the sun darkened in an alarming manner on August 19; there appeared to be no eclipse by the moon, but rather an interruption from some meteoric substance." There was an eclipse of the sun, annular but nearly total, on the morning of August 14; it is mentioned in the Saxon Chronicle, which tells us "the sun's disk was like a black shield." The near coincidence of dates suggests in this case a connection between the darkness, and the eclipse. In 934, according to a Portuguese historian, the sun lost its ordinary light for several months, and this is followed by the doubtful statement that an opening in the sky seemed to take place, with many flashes of lightning, and the full blaze of sunshine was suddenly restored. In 1091, on September 29, not 21, as given in some of the translations of Humboldt's Cosmos, Schnurrer relates that there was a darkening of the sun which lasted three hours, and after which it had a peculiar colour which occasioned great alarm. In another place we read: "Fuit eclipsis Solis 11 Kal. Octob. fere tres horas: Sol circa meridiem dire nigrescebat": there was no visible eclipse at this time, and the November eclipse was central only in the southern parts of the earth. A century later, or in June, 1191, according to Schnurrer, the sun was again darkened, with certain attendant effects upon nature: here the cause is easily found; on June 23 there was a total eclipse, in which the moon's shadow traversed the continent of Europe from Holland to the Crimea; the eclipse was total in this country between the coasts of Cumberland and Yorkshire. Erman refers to a sun-darkening on February 12, 1106,

which was accompanied by meteors, and we read in the cometographies that on the 4th, or, according to others, on the 5th, of February in this year a star was seen from the third to the ninth hour of the day, which was distant from the sun "only a foot and a half." Matthew Paris and Matthew of Westminster term this star a comet, and we may take it to have been the same which, later in the same month, was observed in China under the sign Pisces, and which at one time was supposed to have been identical with the great comet of 1680; this body, however, would not appear to have been sufficiently near the earth as, even on the assumption of a denser constitution than usual with comets, to account for a diminution of the solar rays, by its intervention. On the last day of February, 1206, according to a Spanish writer, there was complete darkness for six hours. In 1241, "five months after the Mongol battle of Leignitz," the sun was so obscured, and the darkness became so great, that the stars were seen at the ninth hour about Michaelmas. In this case, again, the darkness referred to was undoubtedly due to the total eclipse on October 6, of which Prof. Schiaparelli has collected a full account from the Italian writers. Lastly, in 1547, from April 23-25, Kepler relates on the authority of Gemma, "the sun appeared as though suffused with blood, and many stars were visible at noonday." Schnurrer thought this phenomenon was what the Germans call an "Hohenrauch," notwithstanding the visibility of stars.

From the above brief summary of what have been considered abnormal sun-darkenings, we see that in several cases the diminution of light has been due to the ordinary effects of a total eclipse, while it is clear that there are no grounds in the historical evidence for any prediction of a period of darkness. The nervous in these matters, and it would really appear that such exist, may take consolation therefrom.

GWD-002 [DARK DAY IN NEW ENGLAND]

Anonymous; Nature, 24-540, October 6, 1881.

A remarkable phenomenon occurred in New England on September 6, almost exactly similar to one that occurred in the same region on May 19, 1780. The Springfield Daily Republican describes it as follows:—In this city the day began with a slow gathering of fog from all the watercourses in the early hours, the thin clouds that covered the sky at midnight seemed to crowd together and descend upon the earth, and by sunrise the atmosphere was dense with vapour, which limited vision to very short distances, and made those distances illusory; and as the sun rose invisibly behind, the vapours became a thick, brassy canopy, through which a strange yellow light pervaded the air and produced the most peculiar effects on the surface of the earth. This colour and darkness lasted until about three o'clock in the afternoon, once in a while lightening, and then again deepening, so that during a large part of the time nothing could be done conveniently indoors without artificial light. The unusual complexion of the air wearied and pained the eyes. The grass assumed a singular bluish brightness, as if every blade were tipped with light. Yellow blossoms turned pale and gray; a row of sunflowers looked ghastly; orange nasturtiums lightened; pink roses flamed; lilad-hued phlox grew pink; and blue flowers were transformed into red. Luxuriant morning-glories that have been blossoming in deep blue during the season now were dressed in splendid magenta; rich blue clematis donned an equally rich maroon; fringed gentians were crimson in the fields.

There was a singular luminousness on every fence and roof-ridge, and the trees seemed to be ready to fly into fire. The light was mysteriously devoid of refraction. One sitting with his back to a window could not read the newspaper if his shadow fell upon it——he was obliged to turn the paper aside to the light. Gas was lighted all over the city, and it burned with a sparkling pallor, like the electric light. The electric lights themselves burned blue, and were perfectly useless, giving a more unearthly look to everything around. The darkness was not at all like that of night, nor were animals affected by it to any remarkable extent. The birds kept still, it is true, the pigeons roosting on ridge-poles instead of flying about, but generally the chickens were abroad. A singular uncertainty of distance prevailed, and commonly the distances seemed shorter than in reality. When in the afternoon the sun began to be visible through the strange mists, it was like a pink ball amidst yellow cushions—— just the colour of one of those mysterious balls of rouge which we see at the drug-stores, and which no woman ever buys. It was not till between five and six o'clock that the sun had sufficiently dissipated the mists to resume its usual clear gold, and the earth returned to its everyday aspect; the grass resigning its unnatural brilliancy and the purple daisies no longer fainting into pink. The temperature throughout the day was very close and oppressive, and the physical effect was one of heaviness and depression. What was observed here was the experience of all New England, so far as heard from, of Albany and New York city, and also in Central and Northern New York. In reference to this phenomenon the New York Nation suggests that it may be worth the while of weather-observers to note the approximate coincidence between the interval separating the two dark days in New England (May 19, 1780, and September 6, 1881) and nine times the sun-spot cycle of eleven years.

GWD-003 THE DARK DAY IN NEW ENGLAND

Harding, Charles W.; Nature, 24:557, October 13, 1881.

Referring to your paragraph in last week's Nature (p. 540) about the remarkable phenomenon which occurred in New England on September 6, I find in the recently-published "History of Lynn, Massachusetts," the following—

"1717,——Extraordinary darkness at noonday October 21st; dinner tables lighted."

"1780.——Memorable dark day May 19th; houses lighted as at night. "

GWD-004 THE DARK DAY IN CANADA

Anonymous; Scientific American, 44:329, May 21, 1881.

Montreal was the center of the darkness of 1819. Dark days are rather common, but the electrical and luminous phenomena described below are distinctly unusual.

What was the strangest occurrence of that time, or rather the strangest thing that ever happened in the history of this country, was what has been always known as the "Phenomenon of 1819. " On the morning of Sunday, November 8, 1819, the sun rose upon a cloudy sky, which assumed, as the light grew upon it,

a strange greenish tint, varying in places to an inky blackness. After a short time the whole sky became terribly dark, dense black clouds filling the atmosphere, and there followed a heavy shower of rain, which appeared to be something of the nature of soapsuds, and was found to have deposited after settling a substance in all its qualities resembling soot. Late in the afternoon the sky cleared to its natural aspect, and the next day was fine and frosty. On the morning of Tuesday, the 10th, heavy clouds again covered the sky, and changed rapidly from a deep green to a pitchy black, and the sun, when occasionally seen through them, was sometimes of a dark brown or an unearthy yellow color, and again bright orange, and even blood red. The clouds constantly deepened in color and density, and later on a heavy vapor seemed to descend to the earth, and the day became almost as dark as night, the gloom increasing and diminishing most fitfully. At noon lights had to be burned in the courthouse, the banks, and public offices of the city. Everybody was more or less alarmed, and many were the conjectures as to the cause of the remarkable occurrence. The more sensible thought that immense woods or prairies were on fire somewhere to the west; others said that a great volcano must have broken out in the Province; still others asserted that our mountain was an extinct crater about to resume operations and to make of the city a second Pompeii; the superstitious quoted an Indian prophecy that one day the Island of Montreal was to be destroyed by an earthquake, and some even cried that the world was about to come to an end.

About the middle of the afternoon a great body of clouds seemed to rush suddenly over the city, and the darkness became that of night. A pause and hush for a moment or two succeeded, and then one of the most glaring flashes of lightning ever beheld flamed over the country, accompanied by a clap of thunder which seemed to shake the city to its foundations. Another pause followed, and then came a light shower of rain of the same soapy and sooty nature as that of two days before. After that it appeared to grow brighter, but an hour later it was as dark as ever. Another rush of clouds came, and another vivid flash of lightning, which was seen to strike the spire of the old French parish clurch and to play curiously about the large iron cross at its summit before descending to the ground. A moment later came the climax of the day. Every bell in the city suddenly rang out the alarm of fire, and the affrighted citizens rushed out from their houses into the streets and made their way in the gloom toward the church, until Place d'Armes was crowded with people, their nerves all unstrung by the awful events of the day, gazing at, but scarcely daring to approach the strange sight before them. The sky above and around was as black as ink, but right in one spot in mid-air above them was the summit of the spire, with the lightning playing about it shining like a sun. Directly the great iron cross, together with the ball at its foot, fell to the ground with a crash, and was shivered to pieces. But the darkest hour comes just before the dawn. The glow above gradually subsided and died out, the people grew less fearful and returned to their homes, the real night came on, and when next morning dawned everything was bright and clear, and the world was as natural as before. The phenomenon was noticed in a greater or less degree from Quebec to Kingston, and far into the States, but Montreal seemed its center. It has never yet been explained.

GWD-005 DARKNESS AT MID-DAY

G. ; Notes and Queries, 2:3:366, May 9, 1857.

A phenomenon of this extraordinary nature occurred at Bolton-le-Moors and the neighbourhood, about noon on Monday, March 23, 1857. The wind during the morning had been north-east, with a little snow; at twelve o'clock the air became quite still, and a deep gloom overspread the heavens, increasing so rapidly, that in ten minutes it was not possible to read, or distinguish the features of any person a few yards off. This was the more singular from there being no fog at the time, though snow in very minute particles was falling. The extreme darkness continued about eight minutes, when the horizon at two or three points assumed a lurid yellow appearance, as though from conflagrations a few miles distant; within a quarter of an hour from this time the darkness was dispelled; but such was the alarm caused by the phenomenon, that many persons supposed the world at an end, not a few were made ill by intense nervous excitement, and all were more or less impressed with a feeling of awe. Poultry went to roost, instinct being stronger than habit. Can any of your correspondents explain the cause of this phenomenon, or record any similar occurrences?

If darknesses, such as that described above, are due to great fires, where are the reports of the fires and why does no one smell the smoke?

GWD-006 EXTRAORDINARY PHENOMENON

Murray, Charles A. ; Annual Register, 99:132-133, 1857.

The following letter from the Hon. Charles Augustus Murray, Her Majesty's Envoy to Persia, to Sir Charles Lyell, was made public:- "Bagdad, May 23, 1857. My dear Sir Charles,——We have lately witnessed here a phenomenon so strange that a brief description of it may not be uninteresting to you. On the 20th instant, a few minutes before 6 p. m. (which is here about an hour before sunset), I was sitting with my Mirza reading some Persian letters, when on a sudden I became sensible of an unusual obscuration of the light on the paper. I jumped up, and going to the window, saw a huge black cloud approaching from the north-west, exactly as if a pall were being drawn over the face of the heavens. It must have travelled with considerable rapidity, for in less than three minutes we were enveloped in total darkness——a darkness more intense than an ordinary midnight when neither stars nor moon are visible. Groping my way amid chairs and tables, I succeeded in striking a light, and then, feeling assured that a simoom of some kind was coming on, I called to my servants to come up and shut the windows, which were all open, the weather having been previously very sultry. While they were doing so the wind increased, and bore with it such a dense volume of dust or sand, that, before they could succeed in closing the windows the room was entirely filled, so that the tables and furniture were speedily covered. Meanwhile a panic seized the whole city; the Armenians and other Christian sects rushed through the gloom to confess and pray in the churches; women shrieked and beat their breasts in the streets and the men of all classes prostrated themselves in prayer, believing that the end of the world had arrived. After a short time the black darkness was succeeded by a red, lurid gloom, such as I never saw in any part of the world, and which I can only liken in imagination to the effect that might be produced if all London were in conflagration in a heavy November fog; to me it was more striking (I may almost say fearful) than the previous utter darkness, and reminded me of that 'darkness visible' in which the poetic genius of Milton placed the demons

and horrid shapes of the infernal regions. This lurid fog was doubtless occasioned by the rays of the western sun shining obliquely on the dense mass of red sand or dust which had been raised from some distant desert, and was borne along upon the blast. I enclose you a specimen of the dust. The Arabs here think that it came from the Nejd. The storm seems to have travelled in a circular direction, having appeared first from the south, then south-west, then west, then north-west. After about two hours, it had so far passed away that we were able to open the windows again and breathe the outer air. It cannot have been a simoom, for during those which I have experienced in Arabia and Egypt the wind is hot and stifling. On the 20th the wind was high, but only oppressive from the dense mass of dust that it carried with it. " Professor J. Quekett, having examined a specimen of red dust from Bagdad, which accompanied Mr. Murray's letter, detected under the microscope only inorganic particles, such as quartz, sand, and, though a small portion of calcareous matter was present in the sand, yet he could observe no microscopic shells or other organic matter.

GWD-007 A DARK DAY IN WASHINGTON

Eells, M. ; Monthly Weather Review, 30:440, September 1902.

Friday, September 12, 1902, was the darkest day that the oldest inhabitant of Hood Canal, in western Washington, ever knew here, owing largely to the smoke from heavy fires in western Washington and western Oregon. At Twana, in Mason County, it appeared as follows: The evening before was somewhat smoky, though not peculiarly so, with a few ashes occasionally falling. About 3 o'clock on the morning of the 12th the whole heavens were a very bright red, according to the statement of a young lady who waked up, as she supposed, about that time, the light being similar in appearance to a certain kind of northern lights only it covered the whole heavens. By 5-30 a. m. , when the writer first looked out, it had faded to a dull red. By 7 a. m. the reddish appearance had disappeared, it having turned to a gray color. At 9 a. m., it was possible to read in the house only by getting near a window, and even then it was quite trying to the eyes. By 11:30 a. m. the dull reddish color appeared all around, soon growing very bright in the north, but by 12-30 p. m. the brightest red was in the south. Between 12 noon and 1 p. m. was the darkest part of the day, it being utterly impossible to read out of doors. After 1 p. m. it began to lighten a little, the chickens, which had gone to roost, began to crow; 1:15 p.m. it was again possible to read out doors; at 2 p. m. there was considerable dull red in the sky, but it then disappeared to be seen no more, the heavens becoming again of grayish color. After 3 p. m. was the brightest part of the day.

What caused the reddish appearance has not been satisfactorily explained. Some attributed it to the light from the fires, but this does not seem possible. The writer attributes it to the sun's rays working through the darkness, until he learned that the brightest red was seen about 3 a. m. There certainly seems to have been a very peculiar state of the atmosphere that day, which can only be explained by wiser meteorologists than the writer, but the day will be remembered as one in a lifetime.

GWD-008 DARK DAYS AND FOREST FIRES

Talman, C. F.; Scientific American, 112:229, March 6, 1915.

Instances of daytime darkness are recorded in the old chronicles along with such other "prodigies" as multiple suns, showers of blood, and warring armies in the sky——all of which can easily be identified to-day with well-known meteorological phenomena (parhelia, rain reddened with desert dust, and the aurora). The two famous cases mentioned in the Bible——the plague of darkness in Egypt and the darkness attending the crucifixion——illustrate the fact that such occurrences were once universally assumed to be miraculous.

Some of the early cases of daytime darkness mentioned in history are doubtless attributable to solar eclipses, and must, accordingly, have been restricted to a small part of the earth's surface, and have been of but a few minutes' duration. The majority of the famous "dark days" were, however, the result of an abnormal accumulation of smoke or dust in the air, sometimes arising from burning forests, moors, or prairies, sometimes from volcanic eruptions, and in many instances covering vast areas of the globe.

In a recent publication on "Forest Fires" (Forest Service Bulletin 117), Mr. F. G. Plummer gives the following list of dark days in the United States and Canada:

1706——May 12th, 10 A.M., New England.
1716——October 21st, 11 A.M. to 11:30 A.M., New England.
1732——August 9th, New England.
1762——October 19th, Detroit.
1780——May 19th, New England. (Black Friday. The Dark Day.)
1785——October 16th, Canada.
1814——July 3rd, New England to Newfoundland.
1819——November 6th to 10th. New England and Canada.
1836——July 8th, New England.
1863——October 16th, Canada ("Brief duration.")
1868——September 15th to October 20th, Western Oregon and Washington.
1881——September 6th, New England. (The Yellow Day.)
1887——November 19th, Ohio River Valley. ("Smoky Day.")
1894——September 2nd, New England.
1902——September 12th, Western Washington.
1903——June 5th, Saratoga, N. Y.
1904——December 2nd, 10.A.M., for 15 minutes, Memphis, Tenn.
1910——August 20th to 25th, Northern United States, from Idaho and Northern Utah eastward to St. Lawrence River.

Forest fires are the common cause of dark days in this country. The fact that such days are most frequent in the Northeastern United States and Eastern Canada is evidently related to the fact that practically all barometric depressions ("lows"), with their attendant whirl and indraft of the surface air, pass down the St. Lawrence Valley on their way to the ocean, and usually become intensified and sharply defined in this region. The smoke from a conflagration anywhere on the periphery of a "low" is drawn into the vortex along more or less converging lines, and at the same time rises to a considerable altitude. Eddies in the circulation of the "low" will result in a dense accumulation of the smoke in places, and this may occur above the level of the lower clouds, which thus mask the cause of the phenomenon. Hence the startling effect of darkness in the daytime, often with little or no turbidity of the air near the earth's surface. Mere smokiness of the air near the ground or a fog heavily charged with

smoke (as in the case of the London fogs), however great the obscurity produced, would hardly be placed in the same class with the awe-inspiring dark days of the chroniclers. If, however, showers occur during one of these occurrences, a large amount of soot is likely to be brought down, and thus we have another "prodigy"; viz., "Black rain." A very recent case of this sort is reported in the Quarterly Journal of the Royal Meteorological Society for October, 1912; during a thunderstorm in Eastern Hampshire darkness almost like that of night occurred in the early afternoon, and inky rain fell. The phenomenon was due to soot carried from London, fifty miles away.

When the pall of smoke is rather thin a certain amount of sunlight struggles through, and owing to the same process that gives us the golden glow of sunset a yellow or coppery tinge is cast over the landscape. This effect has been noted in connection with several dark days, including the most famous of all, that of May 19th, 1780. It was the principal feature of the dark day of September 6th, 1881, in New England, which is accordingly known as "the yellow day."

The great Idaho fire of August, 1910, was responsible for dark days over an area larger than in any other case on record in this country. The accompanying chart, from the Forest Service Bulletin above mentioned, shows the area in which artificial light was used in the daytime, but smoke was observed far beyond these limits. The British ship "Dunfermline" reported that on the Pacific Ocean, 500 miles west of San Francisco, the smell of smoke was noticed, and haze prevented observations for about ten days.

GWD-009 THE YELLOW DAY IN SEPTEMBER 1881

Anonymous; Weatherwise, 25:118, June 1972.

The outstanding dark day of the 19th Century occurred on 6 September 1881 when smoke from forest fires in Michigan and Ontario filtered the sun's rays over the Northeast to produce an eerie atmosphere of yellowish and brassy hues. Though not as completely black as in May 1780, astronomers at Harvard estimated after some experiments that only one-tenth as much light was received from the sky as on an average cloudy day.

The Weather Bureau observer at Albany, N. Y described the event: " 5 a. m. a few stratus clouds in the lower atmosphere together with what appeared to be light smoke, the latter gradually increased in density until 7:30 a. m. when the entire heavens were hidden and from 8 to 9:40 a. m. it was so dark that artificial light was necessary to enable business to be transacted. The color of the atmosphere was yellow or light brown as the density of the smoke appeared to increase or decrease and a remarkable effect was produced on all objects upon the earth's surface. Grass and all objects of green color were made to appear unusually bright, while blue changed to purple or pink. The smoke did not extend immediately to the earth's surface, but hung as a cloud of low elevation. No smell of smoke was detected at any time; the sky became clear at 11:30 a.m." Cambridge, Mass., 150 miles to the east, experienced the greatest yellow effect in early afternoon; it gradually disappeared after 4:00 p.m. and was not noticeable after 6:00 p.m.

In the present century the most notable obscuration occurred from 25 to 30 September 1950. This was described by Dr. Harry Wexler: The Great Smoke Pall. Weatherwise, 3-6 (Dec. 1950), 129-34, 142.

GWP-008 A WATERSPOUT

Wethered, E.; Nature, 18:194-195, June 20, 1878.

The author hypothesizes a waterspout but this incident should really be considered along with other examples of point rainfall.

Among the meteoric phenomena of which we have heard recently, not the least interesting occurred on Thursday the 14th near the Kelston Round Hill, about three miles to the west of Bath. Shortly after five o'clock in the evening the inhabitants of the village of Weston, which lies between Kelston Hill and Bath, were startled by a volume of water advancing like a tidal wave along the Kelston Road; in a minute the water was upon them, flooding the houses and laying the main street four feet deep under water; with such force did it come that a stone weighing five hundred-weight was carried several yards, while smaller ones were taken a much greater distance.

It was not known in the village from where the water had come, but it so happened that about five o'clock I was proceeding to Weston Station by the Midland Railway from Bristol to Bath, and when in sight of the Round Hill I was struck by the blackness and lowness of the clouds in its vicinity. Suddenly there was a flash of lightning, and immediately after the Hill was enveloped in what appeared to be a storm of rain of unusual density.

On arriving home I was not altogether surprised to find the commotion in the village, and I at once attributed the source of the water to the cloud which I had seen; I therefore made my way in the direction of Kelston Hill.

On arriving under the brow of the Hill it was very clear that something more than an ordinary storm had occurred. Near the end of a lane (Northbrook) leading to some fields, the hedge on the right for some yards was lying in the road, but the field beyond at this point presented only the appearance of an ordinary storm, while the lane itself was like the bed of a river. To the left was a field of standing grass; for about twelve feet from the hedge the grass remained intact, then for about the same distance it was as though it had been mown down. This torrent, for such it might have been compared to, came to almost a sudden termination a little above the end of the lane, but it extended down the Hill till it was joined by two others, one of which had carried a hedge away bodily.

The increased volume of water then poured down over some gardens, uprooting trees and vegetables; in less than ten minutes the hedges were lost sight of, and the water rose to a height of eight feet. This was occasioned by a block caused by an arch, which carried off the water from a small stream, not being large enough to take the increased volume. Finally it burst over, scooping the ground out in front of some cottages several feet deep and flowed on as a river some yards wide, again destroying gardens in which were valuable stocks of vegetables.

Near this point the volume of water was again increased; in all five distinct water-courses could be made out, all of which had done considerable damage to grass, cornfields, and gardens. Finally, all united in one body and poured into the village of Weston, levelling three walls as it came, and thence passed into the river Avon.

I gather from spectators at Kelston Hill that it began to be cloudy at half-past four in the afternoon; at five there was a rattling clap of thunder, followed by a downpour of rain——in "bucket-fulls," as one expressed it; but all seemed to agree that the greater portion of the water fell under the brow of the hill, where it came down in several columns. There were no houses close to the spot; had there been they must have been washed away.

GWP-009 PRECIPITATION ODDITIES

The atmosphere had been perfectly still all day, but very sultry. Heavy rain fell in the neighbourhood, and the storm to which I have referred specially was accompanied with hail, which in a few minutes covered the ground some inches deep.

What I have described is no doubt what is popularly termed a waterspout.

The several columns of intense precipitation are intriguing. Many falls of fish and other unusual objects (Section GF) are also highly localized.

GWP-009 THE NOTES OF CHARLES FORT

Fort, Charles; The Fortean Society Magazine, 1:14, September 1937.

1809, June 9. 5 p.m. Cascade of water and hail poured in a torrent upon London upon a space not more than 200 acres. Symon's Met. 47-140.

Another case of "point rainfall. "

GWP-010 REMARKABLE POINT RAINFALL AT GREENFIELD, N.H., EVENING OF AUGUST 2, 1966

Lautzenheiser, R. E., et al; Monthly Weather Review, 98:164-168, February 1970.

1. INTRODUCTION

An excessive rain of amazingly small areal extent fell late on Aug. 2, 1966, at Greenfield, N. H. This note describes the storm, presents related storm statistics, reviews briefly the synoptic situation, and mentions the danger of interpreting point rainfall data as being representative of an area.

2. THE GREENFIELD STORM

Mr. Robert H. Stanley, of Pine Ridge Road, Greenfield, in southern New Hampshire, reported a remarkable rainstorm occurring late on Aug. 2, 1966. A total of 5. 75 in. was measured in a V-type plastic gage of 6-in. capacity. This type of gage is of reasonable accuracy in comparison with standard ESSA-Weather Bureau standard rain gages (Huff 1956). Mr. Stanley has observed weather for many years and is conscientious about the accuracy of his records. While 5. 75 in. may not be an exact figure, it is believed to be substantially correct.

Mr. Stanley's locale is 1. 5 mi northeast of Greenfield, of about 900 ft. at an elevation above sea level. It is situated on the southern slope of a gentle ridge running generally east-west and lies about 2.4 mi south-southeast of Crotched Mountain, which has peaks with elevations just over 2, 000 ft.

Rain began at about 1900 EST, or about an hour before the outbreak of more generalized showers in the region. It soon became a downpour, continuing until about 2300 EST, at which time Mr. Stanley went to bed. It was then still raining, but had slackened noticeably. The rain may have stopped by midnight. A remarkable nonvariability of the intense rain was noted by Mr. Stanley. There was very little slackening, even for brief intervals, during the period of heaviest fall, which was from about 1945 to 2215 EST. There

was practically no wind. Neither thunder nor lightning was observed. The noise on the roof was terrific, like that of a continuous waterfall. A plastic bird feeder mounted on the side of the house was broken by the impact of sheets of water from the eaves. Looking out the window, Mr. Stanley could see stones and gravel from the roadway, south of the house, being washed away by torrents of water.

Upon rising in the morning, Mr. Stanley noted that the weather had cleared, with a brisk westerly wind. After finding the 5.75 in. of rain in the gage, he inquired from a neighbor 0.3 mi to the east. He found that the neighbor had but 0.50 in. in his gage. He thereupon examined the countryside for visible effects. The road washout extended for only a few hundred feet. Upon going one-half mile in either direction, no evidence of rain erosion of sand or gravel could be found. South of the house, beginning at the gage which was mounted on a pole, well distant from structures or trees, there stretches a 10-acre field. The knee-high grass therein was beaten down flat. By afternoon it began to revive. By the following noon it was erect. To the west of the house, a dry-wash brook running bankful at dawn was empty by 0800 EST.

Drawing a line around the traces of erosion, one obtains an oval area about a mile north-south and about three-fourths of a mile east-west. Within this area, rain varied from the order of 1 in. on the limits to almost 6 in. in the center. Outside this limit, rain is believed to have fallen off sharply to less than one-fourth of an inch, generally within a few thousand feet.

The oval area of the fall resembles the strip-shaped areas in which fish and other objects are reputed to fall. The dispersion patterns of material entering the earth's atmosphere and impacting the surface have similar effects.

GWP-011 SNOW WITHOUT CLOUDS

Anonymous; Monthly Weather Review, 45:13, January 1917.

A phenomenon much more frequent and much better known than rain from a clear sky is the formation and slow fall of snow in the lowest layers of the air under a cloudless sky. This phenomenon occurs only during severe cold and in calm air. The snow crystals and ice particles, sparkling in the sunlight, are particularly small and sparsely distributed, so that they do not darken the air. There are large numbers of ice needles among the forms, and therefore the phenomenon has been called simply ice needles (Eisnadeln) and even has been given an independent symbol; but there also occur beautifully formed stellar and tabular snow crystals, together with structureless ice granules.

The phenomenon is most frequent in the polar regions, where it early attracted the attention of explorers and more particularly because it is often associated with halo phenomena. It has received the name "diamond dust" (Diamantstaub), a name known to the whaling master Martens (1671) mentioned on page 388 and footnote 20. In Germany many a winter passes without developing the phenomenon, but Bodman observed it 28 times within 18 months on the Swedish Antarctic Expedition, and Helm saw it even 26 times in 9 months while on the second German Antarctic Expedition. It appears from the photomicrographs of the "diamond dust," made on the latter expedition and also by Dobrowolski, of the Belgian Antarctic Expedition, that besides needles and tablets prisms are abundantly present, but the latter only at very low temperatures.

GWP-012 PRECIPITATION ODDITIES

GWP-012 CONTINUOUS RAIN

Chapin, H. E.; Science, 21:94, February 17, 1893.

A remarkable phenomenon was observed in the town of Athens, Ohio, late in the fall, which has awakened wide interest, viz., continuous rain during a succession of clear, beautiful days. This was noticed extending for a considerable distance just below the crest of a hill, and lasted through the day, from soon after sunrise till about sunset. The drops of water were at no time large, but they reached their maximum size about two or three o'clock in the afternoon.

The subject attracted the attention of professors in the Ohio University, and it was soon determined that the phenomenon must be due to the precipitation of vapor which had been carried through an old railroad cut for several hundred yards. There had recently been completed and set in operation extensive brickworks, where three large ovens were continually in operation, and from which hot currents of air steadily shot upwards. In the moulding of the bricks, water is mixed with clay, and an enormous amount of hot, watery vapor was passing into the air above the ovens, supplemented by large quantities from the stacks of a large "dryer," which was kept at a high temperature. It is estimated that in all fully forty-five tons of water were at this season daily evaporated.

The plant is situated in the valley of the Hockhocking River, close to a cut made many years ago for a projected railroad, and this cut leads directly to the rise of land where the observations were made. The observer at the University Weather Station reports that the prevailing wind was at this time in a direction such as would carry the hot air, laden with moisture, through this artificial passage. The air was, in all probability, carried partly up the hill and there dissipated along the side. About this time it must have come in contact with a cold current near the crest of the hill, and precipitation followed, causing this unusual rainfall. The conclusion that the precipitation was due to these causes is strengthened by the fact that not until the manufacture of bricks at this place was begun was any such phenomenon observed, so far as is known.

GWP-013 REMARKABLE HAILSTONES

Symons, G. J.; Nature, 41:134-135, December 12, 1889.

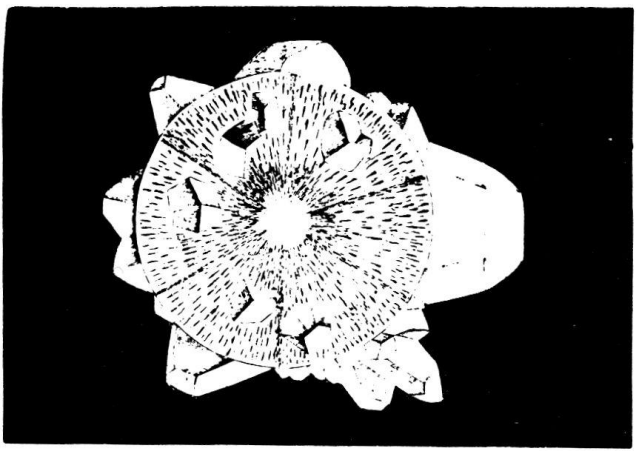
On p. 43 of the present volume of Nature the following extract is given from a paper by Prof. Houston in the Journal of the Franklin Institute:——"On some of the hailstones, though not on the majority of them, wellmarked crystals of clear transparent ice projected from their outer surfaces for distances ranging from 1/8 to 1/4 of an inch. These crystals, as well as I could observe from the evanescent nature of the material, were hexagonal prisms with clearly cut terminal facets. They resembled the projecting crystals that form so common a lining of geodic masses, in which they have formed by gradual crystallization from the mother-liquor. They differed, however, of course, in being on the outer surface of the spherules. "

It is evident from Prof. Houston's paper that this peculiar form of hail was unknown to him, and, as it must also have been unknown to many who have propounded theories as to the formation of hail which will not account for it, I think that a service may be rendered to meteorology by the reproduction of

three of the exquisite lithographs of this form of hail given in Prof. Abich's paper, "Ueber krystallinischen Hagel im Thrialethischen gebuge, " published at Tiflis in 1871. The hailstones represented in Figs. 1-3 all fell on June 9 (21), 1867, at Bjeloi Kliutsch, a village about twenty miles south-west of Tiflis, and 12,425 feet above sea-level (lat. 41° 44' N., long. 44° 30' E.).

Theories of the formation of hail are almost innumerable. I was reading a pamphlet not long since which contained summaries of, I think, twenty-three theories. Some——like Prof. Schwedoff's, that hailstones come from interplanetary space (Brit. Ass. Report, Southampton, 1882, p. 458)——are very droll; but the subject is a very difficult one, and one upon which I do not know of a single good treatise in our language. Possibly, the reproduction of these figures may induce someone to prepare an exhaustive memoir. I could place a large amount of historical and theoretical material at the disposal of any competent person who would undertake the preparation of such a work, it being quite impossible for me to do it myself.

See GFI for ice falls, which might indeed come from outer space!



Curious crystalline hailstone described in GWP-013.

GWP-014 PRECIPITATION ODDITIES

GWP-014 GIANT HAILSTONES — TEMPERATURE CONTRASTS

Pratt, F.; English Mechanic, 84:18, August 10, 1906.

In reply to Mr. Godden (letter 735, p. 601), I may say that I alluded to a report in the Daily Express of July 5 of the storms in Spain, in which "hailstones as large as oranges smashed in the roofs of houses, injured fifty persons, and destroyed crops." I did not discredit the report, as there are many records of what are Called "ice storms" in this country——one, mentioned in Webster's "Recurring Atmospheric Periods" (p. 56), on Aug. 31, 1820, extending from London to the south coast:——"The hailstones were of immense size, and pieces of solid ice 18 in. by 6 in. Two thousand dead sparrows picked up in the streets and suburbs of Worthing next morning."

Another is of the "Great Ice Storm" of July 23, 1883, in North Lincolnshire, in which the fall was described as one of lumps of ice, damaging the crops to £20,000. An eye-witness remarked that they were not like hailstones, but "salt-cellars"; another that they resembled "duck's-eggs"——in fact, they were solid lumps of ice, of every shape and size, weighing from 2 oz. to 6 oz., and some measured 6 in. in circumference. (See Symons's "Met. Mag." 1883, p. 85.)

The original account appeared in the Hull Times. But for the "Press" we should get but few of such interesting details, so I think Mr. Godden might temper his strictures with a little more generosity.

As to the "fall of 14° in London" he inquires about, it was announced in the Express under a heading of "giant" capitals: "Heat Wave Vanishes——Drop of 14° of Temperature!" On the 18th I registered 83°; on 19 and 20th, 65°——a drop of 18, indicative of severe electric storms in remote regions. The inquiry was needless, as Mr. G. must have seen it himself, if he keeps any register of temperature. If not, he ought to be thankful to the "Press" for the "giant" proclamation.

Such drops are not at all uncommon. And, turning over my book of diagrams, I find a remarkable instance among many of such an elevation and "drop" of max. temperature between the 9th and 17th of April, 1869, the earth passing between the sun and Jupiter, complete on the 17th. Commencing with the "transition" of the 9th at 48 , it rose through 66°, 76°, to 79° to the 14th, then a "drop" through 63°, 54°, to 49°——thus a rise and "drop" of 30° and 29° in eight days. Further still, the niin. temp, dropped on the 17th to 35°, thus a total range of 44 from the 14th.

Another remarkable period was that the April of 1865, in the Neptune period at the close. 22nd the maximum marked 80°, ranging between that and 76° on the 28th, when the position became complete. 29-30th the drop was to 58°; Aug. 1 49°, with a min. of 34°, a drop of 18° in max. and 42° total range. Of this period I took advantage to let a little light in upon the Weather Department, with two or three of the officials of which I had had conversations in the Meteorological Society upon the planetary system. I therefore, on the 24th, sent a letter to Mr. F. Gaster, at the office drawing his attention to the heat then prevailing, the influence of the remote planet Neptune, and to the most probable change on the 28th. This was fulfilled, and broke the record of their twenty-four hours' "warnings." Forty years have since elapsed, over half a million of money has been spent, and yet they have got "no forrader." 10,000 more is wanted for more "observations," millions of which are already lying in the Government catacombs, utterly useless, for "want of brains to discuss them" (Symons). As to the 186-years cycle mentioned by Mr. Godden, I know nothing

of it. The only so-called cycle I know of is that of Uranus and Neptune, of 172 years, now in operation, and the cause of the anomalies and extremes we are experiencing, as in 1735.

The temperature changes are not unusual in themselves, but the link to planetary position is.

GWP-015 HAILSTORM ON THE ST. LAWRENCE

Anonymous; Monthly Weather Review, 29:506-507, November 1901.

The following account was submitted by H. S. Chandler. The storm occurred on August 8, 1901, on the St. Lawrence River, opposite the village of Alexandria Bay.

Next came a heavy fall of rain, which was followed by hail. The hailstones to fall were formed as though icicles the size and shape of lead pencils had been cut into sections about three-eights of an inch in length. These were soon followed by others as large as walnuts, and later by still others slightly disk shaped, measuring fully 3 inches in diameter by 2 inches in thickness. The ground was covered with them, and several branches of trees were broken off. They were exceedingly hard and would rebound, when falling on the rocks, without breaking. They melted very slowly even when placed in the sun. When half melted many had the appearance of the human eye——a pupil in the center and a ring surrounding it, with fine lines radiating in all directions. Others were composed of hard crystals of ice, several stones often being frozen together; and still others were of frozen snow. The next morning at 8 o'clock remnants of hailstones as large as peas were lying on the ground.

During the storm the river presented a beautiful appearance, there being thousands of miniature fountains from a foot to 6 feet in height spurting up where the hf»il plunged in.

GWP-016 ACCOUNT OF SOME REMARKABLE HAILSTONES WHICH FELL AT PADUA, ON THE 26TH OF AUGUST 1834

Cosari, D. L.; Edinburgh New Philosophical Journal, 19:83-88, 1835.

Hailstones of a Flattened and Irregular Shape. (1.) Some of these fragments of ice presented the appearance of an angular plate, of about an inch in thickness. Across one of these surfaces, which was nearly flat and transparent, might be perceived fine plates, some of which were rectilinear, and others curved, opaque and whitish, which alternated with other plates of transparent ice, which were not concentric, but nearly parallel to the largest of the lateral faces of the plate. Adhering to the opposite surface, there was also seen crystals of very pure and transparent ice, quite distinct from each other, but interlaced among themselves. They were inclined on the surface, and stood at an angle of about 45°; the length of these crystals was nearly an inch and a half, and their form that of a four sided prism, one side of which was very small in comparison of the other three. Each prism was terminated by a

pyramid which had also four sides. The plates presented the appearance of a crystallized sediment. The greatest distance comprehended between two of the angles which they formed, varied from four to eight inches.

(2.) It was also observed, that the irregular pieces of ice, which were of a flattened and somewhat double-convex shape, presented a rough surface, with an angular and irregular outline, and mixed with rudimental four-sided prismatic crystals. There were also a great number of a circular and elliptical form. They presented circles or ellipses formed of concentric layers of ice of an opaque whiteness, alternating with transparent layers, in the centre of which there was a white or opaque nucleus. The diameter of these plates of ice was from 1-1/2 inch to 4 inches.

(3.) There were also observed, other pieces of transparent ice, whose surface was rough, and the edge of which, thicker than the rest, formed a kind of border. The edge alone presented striae, produced from three to five alternate plates of ice, sometimes whitish opaque, and sometimes transparent. The centre of the exterior portion was a whitish circle, which appeared the nucleus. The transparent centres of these pieces were sometimes perforated, so as to present, after partial melting, the appearance of a ring of ice, the diameter of which varied from 1-1/2 inch to 3 inches. Many individuals were struck with the appearance which we have just mentioned, (pp. 84-85)

GWP-017 HAILSTONES AT CLEVELAND, OHIO

Herrick, Francis H.; Nature, 50:173, June 21, 1894.

A remarkable hailstorm occurred at Cleveland, Ohio, on the afternoon of Thursday, May 17, of a character to be remembered but probably not repeated during the present generation. Larger hailstones are rarely seen than fell on that day, and very likely few, if any, people living in this part of the country have ever witnessed a more severe bombardment.

The air was intensely sultry up to twenty eight minutes past three o'clock in the afternoon (sun time), when it commenced to rain. Hailstones of moderate size rattled down in profusion,, and it soon appeared that an ordinary thunderstorm had begun. At the east end of the city the wind increased rapidly in force, and it grew very dark. Presently the hail became violent, and for about twenty minutes the streets and lawns presented a most animated appearance. The impact of the icy bullets against the roofs of houses sounded like the rattle of musketry. The snow-white balls glistened upon the close-cropped lawns, where they kept up a lively dance, and in the street were shattered against the flags and paving stones.

The stones, many of which were as large as billiard balls, and some of the size of goose eggs, weighed from one to five or six ounces, and probably many that fell were much heavier than this. Their shape was very various, some being spheroidal, others discoidal or exceedingly irregular. The accompanying figures represent to some extent the forms of two stones which fell on the Adelbert College lawn, and were picked up by some of our students.

A hailstone was found by Prof. F. P. Whitman to weigh nearly an ounce and a half after it had melted considerably. Its measurements were 2-3/4 x 2-1/2 x 1-1/4 inches. The surface was fissured and raised into tubercles, while many others had an exaggerated mulberry appearance, suggesting a composite structure. Sections of such stones showed, however, that they were as a rule formed about a single nucleus, and were not the result of the regela-

tion of a number of separate pellets.

The specimen represented in Fig. 1 measured three inches in length, two in breadth, and about one in thickness. There were two opaque central masses, the larger of which contained the original nucleus, while the smaller spot probably represents a stone which became welded to the larger and older one.

A somewhat flattened, or discoidal form, which was very common, presented a beautiful agate-like core, embedded in a clear mass. A section of one of the stones, which was sawn in two, is shown in Fig. 2. There is a central ball of snow-ice, and this is surrounded by alternating light and dark layers of varying density, and by a very much thicker clear, outer envelope, unshaded in the drawing, showing that the stone had passed through at least two distinct regions of condensation. There were also usually one or two thin superficial strata.

A stone which was examined by one of the observers at the United States Signal Office, was 3-1/2 inches long, 3 inches wide, 2 inches thick, and measured 10-1/2 inches in circumference. Another, which fell near Board of Education Building on Euclid Avenue, was weighed and measured by Principal Theo. H. Johnston. It was oval in shape and measured 3 x 2. 5 x 2. 75 inches, and weighed, after some melting, 4-1/2 ounces. The surface of this stone was deeply pitted as by impact of warm raindrops. A second, brought in by one of Mr. Johnston's pupils, weighed 5. 5 ounces. It had a large pear-shaped snow-iced centre.

GWP-018 THE NOTES OF CHARLES FORT

Fort, Charles; Th? I'ortean Society Magazine, 1:14, January 1940.

1815, Academy of Science, St. Petersburg (sic) received a case containing specimens of stones that fell during a hailstorm at Wilna, of which some hundreds weighed as much as a pound. Sy. Met. 17/151. See 1844.

GWP-019 HUGE HAILSTONES

Anonymous; Scientific American, 71:371, December 15, 1894.

Prof. Cleveland Abbe includes the following among his notes in the Monthly Weather Review for July: On June 3 a tornado passed northeastward through the counties of Harney, Grant, and Union, in eastern Oregon. The most novel feature attending the disturbance was the hail. It is stated that the formation was more in the nature of sheets of ice than simple hailstones. The sheets of ice averaged three to four inches square, and from three-fourths of an inch to one and a half inches in thickness. They had a smooth surface, and in falling gave the impression of a vast field or sheet of ice suspended in the atmosphere, and suddenly broken into fragments about the size of the palm of the hand. During the progress of the tornado at Long Creek a piano was taken up and carried about a hundred yards.

GWP-020 PRECIPITATION ODDITIES

GWP-020 EXPLOSIVE HAIL

Brown, W. G.; Nature, 88:350, January 11, 1912.

On the afternoon of November 11, 1911, there was a brief storm of explosive hail at this place.

The morning had been unseasonably warm; about noon there were the usual signs of a coming thunderstorm——heavy cumulo-nimbus clouds with a gusty wind——which began about 2.30 p. m. with a slight shower of heavy raindrops; shortly afterwards there were two or three flashes of lightning and thunder, followed by a fall of large hailstones, which on coming in contact with the windows or walls or pavement in many instances exploded with a sharp report, so loud as to be mistaken for breaking window panes or a pistol shot. As the hail fell, the fragments sprang up from the ground and flew in all directions, looking like a mass of "popping corn" on a large scale.

The fall lasted two or three minutes, about half the hailstones being shattered, the ground in some places being nearly covered white with the stones and fragments.

Of the unbroken stones, seventy were gathered. They weighed, roughly, 225 grams. A few were ellipsoidal, the longest axis about 25 mm. in length; most of them, however, were nearly spherical, and somewhat smaller, from 15 to 20 mm. in diameter.

Practically all of them contained a nucleus. In a few of the stones the nucleus was porcelain-like, raspberry-shaped, surrounded by almost colourless spherical layers of ice, for about five-sevenths of the diameter, and then a shell of porcelain-like, snowy ice.

A fair proportion of the stones showed, in addition to the spherical, a radiate structure, which was very apparent as the stones melted in a flat dish, showing the crosssection with great distinctness.

The writer noticed a similar fall of explosive hail about eighteen years ago at Lexington, Virginia. The stones in this fall were much smaller, and attention was directed to the stones by the peculiar way in which they seemed to rebound on striking the ground, which was also due on that occasion to their breaking into fragments, without, however, any noticeable explosion.

GWP-021 [HAILSTONES WITH SPIKES]

Anonymous; Nature, 61:594, April 19, 1900.

During a heavy thunderstorm at Herbertsdale, Cape Colony, on February 25, a remarkable fall of hail occurred. Mr. O. D. Deacon sends us a description of the storm received from his brother, who witnessed it. From this we learn that the hailstones ranged in size from marbles to small hen's eggs, and very many were of the size of turkey's eggs. Some of these had a very peculiar shape, being round and surrounded with spikes so as to present an appearance not unlike a hedgehog when rolled up in a ball, or like a bristly sea anemone. The hailstones were the largest Mr. Deacon had seen during a thirty-seven years' residence in South Africa, and their spiky character is of peculiar interest.

See GWP-001 for similar hailstones.

GWS-001 THE 11-YEAR SUN-SPOT PERIOD, SECULAR PERIODS OF SOLAR ACTIVITY, AND SYNCHRONOUS VARIATIONS IN TERRESTRIAL PHENOMENA

Clough, H. W.; Monthly Weather Review, 60:99-108, April 1933.

Clough's paper is a mine of interesting correlations. Students of "cycles" will not find much new material, but to others these rather extensive quotes will introduce this ancient tendency of man to search for astronomically correlated periodicities.

Synopsis. This paper supplements a former one with corrections and additional matter. A few changes are made in the Fritz epochs of "probable maxima" of sun spots, dating from 300 A. D., and it is shown that the frequency distribution of the 11-year sun-spot intervals derived from the ancient epochs has about the same mean, skewness, and dispersion as that of the Wolfer intervals from 1610. For the whole period of 1,600 years the most frequent interval or mode is computed to be 10. 94 years while the normal length of the period computed by a least-square method is 11. 067 years. The mean deviation from 11. 0 years is ± 1. 69 years.

By appropriate statistical processes and criteria, the sequence of the 11-year intervals is shown to be systematic rather than fortuitous. While the most frequent interval between peaks or hollows in a random sequence is the two-interval, there is a marked tendency for maxima or minima in the solar curve to recur about every third interval. In other words the most frequent interval of recurrence is about 36 years.

The epochs of maximum and minimum length of the 11-year period, derived from the curve of 11-year intervals, yield by the least-square computation a normal length of 37. 5 years for the long period, with an amplitude of 2.4 years. On eliminating the 37-year period by an appropriate smoothing of the 11-year intervals, a still longer period is disclosed with a normal length of about 83 years and an amplitude of 1. 5 years. Further smoothing discloses a 300-year period with an amplitude of 0. 5 year. The 300-year period undergoes a long secular variation in length, roughly estimated at 1,400 years.

Both the 37-year and the 83-year periods undergo a 300-year variation in length, comparable with that of the 11-year period, the maximum lengths being about twice the minimum lengths.

These three periods exist also in the relative numbers and the ratios, a:b, that is, time of increase to time of decrease of sun spots from minimum to minimum, the numbers varying inversely and the ratios directly with the length of the 11-year period.

These periods are apparent not only in auroral data but in various other terrestrial data——frequency of severe winters, frequency of Chinese earthquakes, flood and low stages of the Nile, tree growth in Arizona and California, and wheat prices in England.

The epochs of maxima of the three periods lag somewhat behind the epochs of maximum solar activity, and the amount of the lag is proportional to the length of the period. The lags of the 37-year and 83-year epochs exhibit a 300-year period, also a long secular variation——the lag after 1, 000 A.D. being about two thirds that previously.

The extensive sections on statistics are omitted.

The Periodicities of the Aurora

The 11-year period.——The parallelism between the variations in the fre-

quency of sun spots and auroras is very close. According to Fritz the average lag of auroral maxima after sun spot maxima is about a year.

The 37-year period.——The list given by Fritz has received some additions derived from the Lovering and Short catalogs. The total number of auroras in the 20-year interval centered on every fifth year is plotted in figure 1. Most of the maxima are obvious, but in some cases the unsmoothed or original data must be considered in the determination of a maximum epoch and in other cases data are lacking so that interpolation is necessary. The greater amplitude of the 83-year period is the cause of some uncertainty. The epochs of maxima and minima are given in table 2 with interpolated or doubtful epochs indicated by asterisks.

The 83-year period.——The amplitude of this period is greater than that of the 37-year period, and it can therefore be traced back to 400 A.D. with considerable accuracy. To eliminate the 37-year period from the 20-year summations, a summation of the number for a given date and that of the second preceding and following is made. These summations for every tenth year are plotted in figure 2. The marked increase in the numbers from 1525 is due in part to the secular variation with a maximum about 1550 and in part to the increase in available records following the era of the introduction of printing. In selecting the 83-year epochs in table 3, this secular variation was taken into consideration.

The total number of days per decade with aurora from 1500 to 1740, and the Fritz auroral numbers, 1700 to 1870, averaged by decades, are shown plotted in figure 2. From these curves the epochs were derived after 1600.

The occurrence of aurora has been recorded as far back as 503 B.C., and approximate epochs of maximum frequency have been derived from the lists given in the various catalogs. These are given in table 3 with two interpolated epochs indicated by asterisks.

The 300-year period.——The number of years in each half-century from 350 A.D. to 1750, in which aurora was recorded, is plotted in figure 3. The epochs of maximum and minimum frequency are given in table 4.

Tabulation of the 83-year auroral epochs.——Figure 7 shows the 83-year epochs in a table with rows 330 years long. Full lines join epochs of maxima separated by four 83-year intervals. Epochs of minima since 400 A. D. are plotted and joined by dashed lines. The 300-year variation is eliminated from the trend of the lines and their curvature indicates the long secular variation around 1, 400 years which has already been noted.

The trend of the lines is on the whole slightly to the left, indicating a period length of approximately 82 years.

The two graphs, figures 6 and 7, are derived wholly independently of each other but the curvatures of the lines are virtually identical.

Severe Winters in Europe

Records of unusual meteorological events are abundant in European literature. The occurrence of severe winters has been very consistently recorded, and Bruckner, by means of this material, was enabled to extend his 35-year cycle, deduced from modern instrumental records, back to the year 1000, The reader is referred to my 1905 paper for a discussion of his results together with additional results derived from my own researches. Bruckner used Pilgram's catalog and began with the year 800 but he regarded the records previous to 1000 as of little value.

To extend the series backward, I have used Hennig's catalog which is very complete. Easton's list was also consulted. Employing the method used by Bruckner, the total number of severe winters in the 20-year interval centered

on every fifth year were counted and the numbers from 340 to 1030 together with his numbers from 1030 to 1775 are shown graphically in figure 1.

The 37-year period.—Maxima and minima are quite definitely apparent except in a few instances where data are lacking. The maximum and minimum epochs are given in table 2 with interpolated epochs indicated by asterisks.

The 83-year period.—In order to eliminate the 37-year period a smoothing process similar to that used on the auroral numbers was employed, and the smoothed values for every tenth year plotted in figure 2. The derived epochs of maxima and minima are given in table 3. Epochs previous to 300 A.D. are only approximate.

The 300-year period.——In Brooks' "Evolution of Climate" the number of severe winters in Europe per half-century are given from 800 A. D. and I have extended the data back to 300 A. D. from Hennig's catalog. These numbers are shown in figure 3.

Flood and Low Stages of the Nile

A remarkable series of yearly records of high and low levels of the Nile at the Roda gage, Cairo, from 622 A. D. to 1470 has been published by Prince Omar Toussoun. The original records are in cubits and dated in Mohammedan years. One list from 640 to 1451 was published in 1923. Another list from 622 to 1470 in metric equivalents and corrected to the modern calender was published in 1925. These two lists differ slightly and after careful examination of the graphs of both lists it was decided to use the first one, making a few corrections to readings, evidently misprints, by comparison with the later list and supplying a number of missing years. Five-year means have been computed for both flood and low stages.

The 11-year period.——The influence of the 11-year solar period on the flood stages is shown by an excessive predominance in the 5-year means of the two-interval over the normal frequency for random numbers, 50 percent vs. 40 percent. As for the minima there is a relative excess of the four- and five-intervals, indicating a 20- to 25-year period.

The 37-year period.—When the pentad means of the flood stages are smoothed by the formula, (a+ b) -i- 2, the 11-year period is eliminated and the longer periods can be recognized. The smoothed means are shown in figure 1. Epochs of the 37-year maxima and minima corrected to the Gregorian calender are given in table 2.

The 83-year period.—The contrast between the flood and low stages, both in their origin and in the short periods shown by the pentad means, is further shown by the longer periods. The 37-year period is best shown by the flood levels while the longer periods are best shown by the low stages. Figure 2 shows 10-year means of the low stages smoothed by (a+ b) + 2.

The 37-year period somewhat obscures the longer period in the curve of flood stages, but the epochs of the longer period are nearly coincident in the two curves. Averages of the two series of epochs are given in table 3.

Brooks made a periodogram analysis of the Nile flood data using the same list as that published in 1923, and found that a period of about 77 years is the only period that could be regarded as real, judging from the mathematical criterion.

The 300-year period.——Fifty-year means of the low stages of the Nile are shown plotted in figure 3. The 300-year variation is clearly evident. This long period can be seen also in the curve of flood stages and the maxima and minima of the two curves are virtually identical. The secular increase in the levels of both high and low stages is due to the raising of the Nile bed by the deposition of the silt which it brings down.

Wheat Prices in England

In a paper published after his "Klimaschwankungen", Bruckner concluded from an examination of wheat prices in western Europe for 200 years that high prices occur during or shortly after periods of maximum rainfall. Beveridge computed yearly index numbers of wheat prices in England from 1500 to 1870 by expressing them as a percentage of 35-year moving averages. His periodogram of wheat prices shows a period of considerable amplitude at 35. 5 years.

I have taken Rogers' wheat prices in England from 1265 to 1700 and formed index numbers by expressing the 5-year means as a percentage of moving averages of 7 pentad means. From 1700 to 1870 5-year means of Beveridge's index numbers are employed. After 1870, the Sauerbeck index numbers are used. These pentad index numbers, smoothed by the formula (2a+ 3b + 2c) -r 7, are shown graphically in figure 1. Table 2 gives the epochs of maxima and minima. These epochs are virtually identical with the epochs of wheat prices in my 1905 paper.

Tree Growth in Arizona and California

Douglass was an early investigator of tree-growth in its relation to climate. Some of his early measurements were published in Monthly Weather Review, June 1909. Huntington published in 1912 results of his measurements of the tree rings of the California Sequoias.

The 37-year period.——In his "Climatic Cycles and Tree-Growth," volume 1, Douglass gives a table of mean yearly growth of 5 yellow-pine trees measured near Flagstaff, Ariz., dated from 1503 to 1910 and of 2 trees from 1385 to 1503. This record appears to be quite homogeneous. Residuals of 5-year means of these measures from a smooth curve, formed by successive means of 8 values further smoothed by means of 2 terms, were smoothed by the formula (a+ 2b-i- 3c-*- 2d+ e)-=-9 and the final values plotted in figure 1. The 37-year epochs derived from inspection of this curve are given in table 2. Other records from trees in New Mexico, Colorado, and Utah show this variation with epochs nearly synchronous with those of the Flagstaff region.

The 83-year period.——We are indebted to Huntington for an extensive series of measurements of the growth rate of the California Sequoias. His material has been worked over by Antevs who divided it into two groups—— "A", trees growing in dry situations; and "B", trees growing in moist situations. His tables give the total growth for each decade from 1000 B. C.

The trees is moist situations seem to respond to changes in meteorological conditions affecting their growth sooner than those in dry situations, and their variations are somewhat more regular. For these reasons the "B" series of means are sleected to show the 83-year period. The secular trend in these values has been eliminated by taking residuals from successive means of nine terms. These residuals smoothed by (a-f 2b-t-c)^-4 are plotted in figure 2. The 83-year epochs selected from the original and smoothed curves are given in table 3. The epochs derived from the growth rate of trees in dry situations lag about 10 years after these epochs.

For the years previous to the Christian era, the data from trees in both dry and moist situations (Antevs' "C" group) were used, since the total number is small. The 83-year epochs are given in table 3.

The 300-year period.——To show this period, 50-year means of Huntington's Sequoia measurements are plotted in figure 3. The maximum at 800 is weak but is well marked in Antevs' curve "B".

Chinese Earthquakes

A number of catalogs of earthquakes are available for the study of their periodicities. The most extensive one is by Mallet in the British Association Report of 1858. Extensive catalogs of Chinese earthquakes have appeared but there are, especially in the later ones, too many entries for a single large shock, due to the aftershocks and to the large number of provinces reporting it, so that the list is unsuitable for analysis. Turner made a periodogram analysis of the list of earthquakes in China compiled by Hirato, in British Association Report, 1908, since he regarded it as sufficiently homogeneous for this purpose. He pointed out that periods of around 79 and 284 years appeared probable. Hirota's list ends in 1645. Parker's list in British Association Report, 1909, extends from 1640 to 1875, but it lists only the greater shocks. It is, however, internally homogeneous and shows the 37-year period fairly well.

The 37-year period.——1 have counted the number of shocks in these two lists for each 20-year period, as in the case of severe winters, and the number for each fifth year is plotted in figure 1. Between A. D. 195 and 225 there are no records owing to the Great Rebellion. Epochs of maxima are given in table 2.

The 83-year period.—Smoothing the earthquake numbers in the same manner as those of severe winters, the 37-year period is eliminated. These numbers by decades plotted in figure 2, show the 83-year period with epochs as given in table 3. Two epochs of maxima are interpolated. One at 220 occurred during the civil war and the other at 1250 is not obvious from the data which seem to be unusually scanty at this time. However, there is a pronounced maximum of Japanese earthquakes near this date. The maximum at 1630 is unreliable owing to the ending of the record around 1640 and evidence from other lists points to 1650 as a more probable date. The 83-year epochs after 1650 cannot be reliably determined.

The 300-yftar period.——The number of Chinese earthquakes per half-century from Hirota's list, and also the numbers derived from Mallet's list, are plotted in figure 3. Previous to 400 A. D., Mallet's data are too scanty to show the secular variation. The number of years per half-century with earthquakes in China, compiled from the list by Gauthier in Bull, de l'Observ. de Zikawei, 1907, is also plotted. This curve shows clearly the 300-year variation and the other two curves are in fair agreement. The numbers in the first half of the third century were doubled owing to the hiatus in the records.

The 300-Year Period

The 300-year period has already been shown to exist in the variations of solar and certain terrestrial data. Other data from literary records have been brought together by Brooks and the variations in these data seem to fit in well with those of auroras, etc. In his "Climate through the Ages", table 22, under Europe (general) and Belgium, the percentage of a to a+ b is an index of the raininess of these regions. Similar indexes for the severity of winters in Belgium were computed by me from Vanderlinden's catalog. From Speerschneider's compilation the percentage of years with heavy ice in Danish waters and the number of winters with ice on the Danish coast were obtained. From Co Ching Chu are derived indexes of the raininess and the number of severe winters in China since the first century A.D. These data are shown graphically in figure 3. To facilitate intercomparison of the variations in these curves, the 300-year maxima are indicated by circles and these are joined by broken lines.

While the data graphically shown in figure 3 are obviously of only limited accuracy there is sufficient agreement among the curves to show that the epochs of cold, wet periods are around 200, 550, 850, 1125, 1350, 1625, 1850. The warm, dry epochs are approximately 350, 700, 975, 1250, 1500, 1725. Brooks in his figure 38 gives a composite curve which he thinks represents the variations of rainfall over the Eur-Asian continent during historical times. The maxima of his curve are approximately 425 B.C., 125 B.C., 175, 525, 850, 1125, 1350, 1600, 1825. These dates agree well with the 300-year epochs derived from the curves.

The epochs of maximum acceleration of the 11-year epochs, derived from curve 4 and given in table 4, precede, 50 to 225 years, the epochs of maxima of rainfall. The lag is variable, being greatest around 800 and least around 1600.

The 1400-Year Period

A long period of approximately 1,400 years was noted above in the variations in the length of the 11-, 37-, 83-, and 300-year solar periods. The 83-year period in the aurora also gives clear evidence of this long period. Since the frequency of auroras correlates closely with that of severe winters in the shorter 37- and 83-year periods, there should be evidences of the long period in meteorological fluctuations. Brooks (loc. cit.) has brought together all available evidence relating to climatic fluctuations during the last 5,000 years. His results should furnish impartial evidence as to the existence of the long period, and a summary follows of the maxima and minima in his climatic curves which seem to recur at intervals averaging 1,400 years. His curves showing variations of rainfall in Europe and Asia indicate well-defined minima around 2200 B.C., 1000 B.C., and 600 A.D. Maxima are shown near 3000 B.C., 1300 B.C., between 800 B.C. and 350 B.C., and near 1300 A.D. The maximum in the first millenium B.D. is the so-called "Classical" rainfall maximum, and the maximum near 1300 is the "Medieval" rainfall maximum. According to Peake, as quoted by Brooks, a period of drought occurring some centuries before 3000 B.C. caused migrations from the interior toward the Baltic, while the great dispersal occurred about 2200 B.C. Brooks places the post-glacial "Climatic Optimum" at this time. Huntington's curve of tree-growth has chief maxima at 4000 B.C. and 1300 A.D. and a minimum at 700 A.D. Brooks' curve of temperature in Europe shows a maximum about 700 A.D. and minima 0 to 250 B.C. and around 1500 A.D. The deterioration of climate in Greenland from about 900 A.D. to 1400 is consistent with these fluctuations in Eur-Asia and North America.

It is clear, therefore, that marked climatic extremes have occurred in the Northern Hemisphere with intervals averaging 1,400 years.

Correlation Between Solar and Terrestrial Variations

In figures 1 and 2, below the curves, the 37-year and 83-year epochs of minimum length of the 11-year solar period are plotted on their respective dates. Next below are the corresponding epochs of maximum frequency of the aurora. Then follow the epoch of maxima for severe winters, Nile levels, wheat prices, tree growth, and Chinese earthquakes. Connecting lines are drawn to show the relations and the varying lags. In general the lags are greater before 1000 A.D. than afterwards.

The 37-year period.——The lag of the auroral after the solar epochs averages 24 years——33 years before 1000 and 15 years after. The lag of the epochs of severe winters averages 56 years——70 before 1000 and 44 after. With reference to the epochs of severe winters, the lag of the Nile flood epochs is 1.5 years; that of wheat prices 5 years; that of Arizona pines 23 years. The rela-

tion of earthquakes to other terrestrial events is uncertain, but assuming that indicated by the lines, the maxima average 13 years earlier than those of severe winters.

The 83-year period.——The lag of the auroral after the solar epochs is 55 years; that of severe winters averages 91 years——107 before 1000, and 79 thereafter. The lag of the Nile stage after severe winters is 8 years, Sequoia growth 63 years. Chinese earthquakes precede severe winters by about 13 years. It will be seen that the lags vary directly with the length of the period and that in the case of severe winters the lag after 1000 is about two thirds that previously. A similar lag was noted above for the 300-year epochs of rainfall. This long-period variation in the lag is probably due to the 1,400-year period.

The 300-year variation in the lag.——There is a well-defined 300-year periodicity in the lag of the epochs of severe winters after the solar epochs in both 37-year and 83-year periods (cf. fig. 3). For the 37-year period, the maximum lag occurs around 360, 715, 975, 1335, 1700; minimum lag 580, 900, 1200, 1540, 1810. These epochs of maximum and minimum lag average 100 years after the epochs of short and long 37-year intervals in table 4. For the 83-year period, the maximum lag occurs around 400, 675, 860, 1235, 1610; minimum lag 525, 780, 1050, 1380, 1775; or about 90 years after the epochs of short and long 83-year intervals in table 4.

These consistent variations in the lags of the meteorological events and their persistency for 1, 500 years afford additional proof of the reality of both the solar and meteorological periods.

GWS-002 THE PARADOX OF THE SUN SPOT CYCLE IN METEOROLOGY

Blanford, Henry F. ; Nature, 43:583-587, April 23, 1891.

Blanford begins with a little summary of the early studies of the influence of sun-spots on the weather. He estimates the status of the subject in 1891 thus:

> The speculation, thus started, was followed up with avidity by a large number of inquirers in different parts of the worlds The intensity of the solar radiation, the barometric pressure, the levels of rivers, lakes, and inland seas, and even such more remote effects of meteorological conditions as are manifested in the prices of grain, the recurrence of exceptional vintages, of famines, and in the activity of trade, were all brought under investigation; and, for some years, this and other scientific journals contained frequent articles, bringing to notice some new instance or supposed instance of a recurrent variation conforming more or less accurately to the well-known solar period of eleven years. It must be admitted that some of these supposed coincidences were based on evidence that was far from convincing; and since the major part of the weather phenomena of the globe failed to show any distinct trace of the influence of the solar cycle, interest in the subject gradually declined, and for the last few years the discussion of the question has been comparatively in abeyance.

Next follows a review of some of the more important correlations, concluding with his statement of his "paradox. "

> We now come to what may be termed the paradox of the whole problem. We

have seen that both the air temperature and that of insolation seem to testify unmistakably to the fact that the sun's heat is greatest when his surface is least spotted, and vice versa. But the evidence of the spectroscope points in a diametrically opposite direction, and so also do Meldrum's and Poey's statistics of the frequency of tropical cyclones, and, as far as it goes, the more dubious evidence of the rainfall, since, in all cases in which any appearance of a periodical variation has been detected, the rainfall is most abundant about or shortly after the epoch of maximum sun-spots, and least about the years of minimum, implying therefore increased evaporation and an increased movement of the atmosphere at the former epoch. The variation of the barometric pressure which has been detected in the Indo-Malayan region on the one hand, and in Western Siberia and Russia on the other, also seems to show that in years of maximum sun-spots a larger portion of the tropical atmosphere is transferred to high latitudes in the winter hemisphere which again implies an increased disturbance of atmospheric equilibrium at that epoch between the tropics and the circumpolar zone, and therefore an increased intensity of the disturbing agent.

GWS-003 SUNSPOTS AND THE WEATHER

Norton, H. W.; Monthly Weather Review, 85:117-118, April 1957.

The possibility that sunspots affect weather, and might be made a basis for long-range forecasting, has been recognized for many years, and their effect on "radio weather" is well known. Recently there seems to be renewed interest in this matter, and it is sometimes said that the subject has become "respectable" among meteorologists. The purpose of this note is to point to evidence that no phenomenon having a period in the vicinity of 10 years has any great effect on weather for at least some weather elements in some places. A single example will be given.

Norton and Brier studied persistence in Greenwich monthly mean temperatures. One hundred years of data, 1764 to 1863, were used and the correlation between months was computed for each interval from one to twelve months inclusive, separately for each of the twelve possible antecedent (or subsequent) months. The 144 correlations, each based on 99 pairs of observations, of which the antecedent fell in the years 1764 to 1862 inclusive, were taken as data for statistical analysis.

It follows, that at the 1 percent confidence level, no such cause accounted for as much as 5 percent of the variance of January mean temperatures at Greenwich during the 99 years 1765 to 1863 inclusive. Meteorologists who find themselves thinking seriously of sunspots as an important cause of terrestrial weather will be well advised to bear this correlation in mind, and to try to develop a hypothesis of sunspot influence sufficiently detailed to include little or no influence on some important weather elements at some locations, before they spend more effort on direct search for sunspot-weather relationships.

This negative paper compensates, in part, for all the Sourcebook entries proclaiming strong positive correlations.

GWS-004 THE RELATIONSHIP OF TOTAL ATMOSPHERIC OZONE TO THE SUNSPOT CYCLE

Willett, Hurd C.; Journal of Geophysical Research, 67:661-670, February 1962.

Abstract. For the 27-year period 1933-1959 inclusive, highly significant negative correlation is found between the relative sunspot number and the worldwide average of total atmospheric ozone. Peak correlation with respect to the present-day 10-year sunspot cycle is found at a lag of 1-1/2 to 2 years of the sunspots relative to ozone. The peak correlation of total atmospheric ozone with the mean latitudinal distance from the solar equator of the total area of sunspots is almost identical in magnitude to that with sunspot number. However, the peak correlation with sunspot latitude is found at a lag of less than 6 months of the ozone relative to sunspot latitude, in the opposite direction to that with sunspot number. This phase difference of the negative correlation suggests that atmospheric ozone is much more sensitive to sunspot latitude than to sunspot number.

It has frequently been claimed that ozone concentration is intimately linked to human health and general vigor.

GWS-005 POSSIBLE CORRELATION BETWEEN ATMOSPHERIC OZONE CONTENT AND COSMIC RAY INTENSITY VARIATIONS

Alexander, Saramma, and Chatterjee, S. D.; Journal of Atmospheric and Terrestrial Physics, 33:831-833, 1971.

Introduction. Some kind of correlation between sunspot activity and atmospheric ozone content was first suggested by Cabannes and Dufay. This was confirmed by Dob so.., Harrison and Lawrence, who found a definite relation between variation of ozone content and terrestrial magnetic disturbances. Indeed an increase in the ozone-value in the middle atmosphere is always associated with magnetic storms.

It is equally well-known that the variations in cosmic-ray intensity is highly correlated to solar activity, though the extent and nature of the modulation is not well established. 'Forbush decreases' in cosmic ray intensity are usually accompanied by magnetic storms of a sudden commencement type. According to Dorman, the principal peculiarities of the profile of cosmic-ray intensity variations during magnetic storm depends upon the way in which the Earth enters a solar stream carrying a 'frozen' magnetic field. Recently, Hatton, Marsden and Willets have shown that the cosmic-ray intensity is well correlated with the emission of the coronal line, A. 5303, from the vicinity of the solar equator.

Since both atmospheric ozone content and cosmic-ray intensity variations are mutually correlated to solar activity accompanied by magnetic storm, it is reasonable to seek some kind of correlation between them. (p. 831)

Discussion of Results. The value of the correlation coefficient is not high, probably due to the seasonal increase in the case of the ozone data and possible instrumental drift during the period in the case of the meson telescope records. A running average of the data might have probably given more significant results.

However, this method could not be utilized in this case because both cosmic ray as well as ozone intensity data were not simultaneously available for some days. Another reason for the low correlation coefficient might be due to the non-linear relationship in magnitude of deviation between the two sets of data. Nevertheless, it appears from Fig. 2, that there is an undeniable tendency for the changes in the daily values to occur simultaneously and in the same sense. This is better evident on magnetically undisturbed days.

Out of 40 days taken into consideration the simultaneity of the peaks and troughs in the same phase in the two sets of measurements, occurred on 29 days, while it appeared to be in the opposite phase on 11 days. It is obvious that more extensive data are necessary to reveal the true nature of the correlation. Nevertheless, some systematic trend is clearly evident even in the preliminary results presented here. (p. 833)

GWS-006 THE WEATHER OF 1911 AND THE ULTRA-VIOLET RADIATIONS OF THE SUN

Ramsauer, Carl; Nature, 89:376-377, June 13, 1912.

In connection with an extremely interesting discussion recently carried on in the correspondence columns of Nature I ventured to direct attention (Nature, December 14, 1911) to the unusual diminution of the ultra-violet radiation from the sun as a possible cause of the abnormal weather of the summer of 1911. My intention was less to explain the particular phenomenon of this summer than to direct the attention of meteorologists to a new point of view. In so far I succeeded, for a series of letters in Nature devoted attention to this point. The fullest treatment was contained in a letter from Mr. L. G. Schultz in the issue of March 14.

I should like to reply briefly to this letter, which, owing to university holidays, I have only lately seen. According to my views, his interesting observation, that for both the middle and end of the year 1911 the state of the weather in South America was diametrically opposite to that in Europe (extremely dry summer in the north with rainy winter in the south, and extremely dry summer in the south with rainy winter in the north) does not contradict my attempt at explanation, but rather.proves its correctness.

With normal ultra-violet radiation from the sun, i.e. with normal production of condensation nuclei, the water vapour formed in the north or south hemisphere will condense again on the same hemisphere if the necessary conditions are brought about by cooling and alterations of pressure. With abnormally small production of nuclei rain will probably not cease all over the earth, as Mr. Schultz seems to conclude, for the evaporated water must come down somewhere or other, but the occurrence of condensation will be rendered more difficult. Consequently it is possible that the water evaporated on the summer half of the earth will first find the required preliminary conditions for condensation on the colder winter half, and so come down there.

In other words, if the abnormal weather of 1911 was conditioned by the decrease of ultra-violet radiation from the sun, then the abnormal dryness on the summer hemisphere had to be accompanied by abnormal rainfall on the winter hemisphere. This is exactly what Mr. Schultz has shown beyond doubt occurred not only for the period of the northern summer, but also for the period of the southern summer. Accordingly, the period of abnormally low ultra-violet radiation of the sun extended over the whole of the year 1911.

GWS-007 COMMENTS ON PAPER BY H.C. WILLETT, THE RELATIONSHIP OF TOTAL ATMOSPHERIC OZONE TO THE SUNSPOT CYCLE'

Mitchell, J. M., Jr.; Journal of Geophysical Research, 67:4093-4094, September 1962.

Apart from its theoretical significance for the meteorologist, the remarkable statistical association reported by Willett [GWS-OQi] between total atmospheric ozone and the sunspot cycle is something of a vindictive tribute to the perserverance of long-suffering students of solar-weather relationships who have become well accustomed to disappointment in studies of this kind.

The statistical analysis is skipped and Mitchell's conclusions are presented directly.

To summarize, Willett's contention that there exists a 'highly significant negative correlation . . . between the relative sunspot number and the world-wide average of total atmospheric ozone' must apparently be qualified in several respects. In particular, the correlation is of morginal significance only, and the ozone data are neither necessarily indicative of world average conditions nor free of potential error due to secular station network changes and to solar-correlated uncertainties in the Dobson spectrophotometer observations. Further, Willett's conclusion that 'ozone is much more sensitive to sunspot latitude than to sunspot number' is of doubtful validity.

GWS-008 THUNDERSTORMS AND SUNSPOTS

M., A. B.; Nature, 46:488-489, September 22, 1892.

About six years ago Prof, von Bezold laid before the Bavarian Academy a memoir relating to lightning-flashes that had done damage to houses in Bavaria. In that kingdom the fire-insurance of buildings is entirely in the hands of the State, and a long series of statistical data on the subject was available.

Two things appeared from this inquiry——first, that those damaging lightning-flashes had enormously increased in the last fifty years (to 1882), much more than the increase of houses; and second, that there was apparently some relation between the phenomena and the sunspot cycle. To each maximum of sunspots corresponded a minimum of damaging lightning-flashes or thunderstorms (only in two cases one year displaced); but between each pair of minima was another secondary minimum not far from the minimum of sunspots. The curve of lightning damage, in fact, shows a double oscillation for each sunspot period, maxima of sunspots corresponding with the better-defined of the two minima of lightning damage. A somewhat similar result had been arrived at by Prof. Fritz from a study of thunderstorms in the Indian Archipelago, but he considered it adverse to the idea of a causal relation between sunspots and thunderstorms.

In an earlier paper to the Bavarian Academy (1874), Prof, von Bezold, from a study of several thunderstorm records, came to the conclusion that "high temperatures and a spotless solar surface give years abounding in thunderstorms." This supposed relation between sunspots and thunderstorms does not seem to have attracted much attention of late years. The object of this note is chiefly to show some curves and figures from thunderstorm records, which, it appears to me, yield further evidence of the relation.

In the diagram herewith are two curves, one for Berlin from 1850, the other for Geneva from 1852. The numbers of days of observed thunder are taken and grouped in averages, each yearly point of the curve representing an average of five years. The vertical scale-figures are to the left. Below is an inverted sunspot curve, with scale-figures to the right. The upper points of the latter are minima, and it will be observed how maxima of the thunderstorm curves occur over them or nearly so; and similarly with sunspot maxima and minima of the other curves. There is not always exact coincidence, but a very considerable correspondence will be noticed. (I do not here reproduce the figures yielding those curves.)

Whether or not we may regard this curve as lending support to the view in question, it may at least prove interesting to observe how our summer thunderstorms have varied in number of late years. The Thunderstorm Committee of the Royal Meteorological Society have not yet, I understand, attacked the question of a possible relation to sunspots. May it not be said, however, that the field looks promising?

GWS-009 SKYLAB ENRICHES SOLAR DATA HUNDREDFOLD

Covault, Craig; Aviation Week, 99:16+, November 26, 1973.

Recent scientific work is finally pinpointing some of the cause-and-effect relationships between sun and earth. Many such relationships were formerly doubted due to the absence of any obvious physical connections.

Recent earthbased studies have indicated that passage near the earth of a solar-induced interplanetary magnetic sector boundary generally correlates with about a 10% reduction in the incidence of large storms in the Northern Hemisphere, according to Oertel.

"What we're in the process of doing right now is to see if this is a highly local effect. If it is, then it may well be that scientists can say every time a sector passes by, certain regions of the earth will get very stable good weathe r. " He said Skylab's contribution to understanding the phenomenon could result from pinpointing coronal holes from which magnetic sector boundaries are believed to result. The boundaries could then be mapped as to their relative positions with the earth, or their intersection with earth's orbit, for more accurate weather forecasting. Oertel said no ground-based technique exists that could pinpoint magnetic sector boundaries as they would relate to local positions on the earth.

GWS-010 COSMIC METEOROLOGY

Broun, John Allan; Nature, 18:126-128, May 30, 1878.

The bulk of Broun's article deals with the influence of sunspots on terrestrial magnetism. Since this effect is no longer considered "strange, " it is omitted. The section on the influence of the moon on the earth's atmosphere, however, is more interesting because the whole subject is now being restudied——even though Broun disposes of weather effects in a condescending way.

The Moon's Influence in producing Atmospheric Variations.——The popular beliefs in the moon's influence on the weather are first disposed of; they are conclusions from unrecorded observations where the coincidences are remembered and the oppositions are forgotten; and they are opposed to strict deductions when all the facts are employed.

Agreeing, as all men of science do, with this decision, the question remains, Whether the moon may not have some slight effect in producing meteorological variations? She reflects, absorbs, and radiates the solar heat; may this heat, in accordance with the thesis, not produce some effect on our atmosphere?

Sir John Herschel had observed the tendency to disappearance of clouds under the full moon; this he considered a fact which might be explained by the absorption of the radiated lunar heat in the upper strata of our atmosphere. He cited Humboldt's statement as to the fact being well known to pilots and seamen of Spanish America. I may add the testimony of Barnardin de St. Pierre, who, in his "Voyage al'Ile de Reunion," says: "I remarked constantly that the rising of the moon dissipated the clouds in a marked way. Two hours after rising, the sky is perfectly clear" ("Avril, 1768"). Herschel also cited in favour of his "meteorological fact," a result supported by the authority of Arago, that rather more rain falls near new than near full moon.

Arago's conclusion that the phenomenon was "incontestable of a connection existing between the number of rainy days and the phases of the moon" was founded on the observations of Schubler, of Bouvard and of Eisenlohr, three series which, on the whole, confirmed each other. Schubler also, as Arago showed, had found that the quantity of rain which fell was greater near new than near full moon. These results, accepted by Arago, have not been noticed by M. Faye when he cites Herschel only, as one of those "men of science who interest themselves in popular prejudices, take bravely their defence in hand and exert themselves to furnish not facts but arguments in their favour." It seems, indeed, to have been forgotten that Herschel's argument was given to explain what he considered a meteorological fact,

M. Faye founds his argument wholly on the conclusions of M. Schiaparelli from a weather register kept at Vigevano by Dr. Serafini during thirty-eight years (1827-1864). The Italian physician entered the weather as clear, cloudy or mixed (misti), or rainy from morning to evening. M. Schiaparelli finds from this register that the sky was clearest in the first quarter of the moon. It has not been remarked that if the moon's heat has any effect in dissipating clouds, as Herschel and others believed, this must be seen best when the moon is near full, that is to say, during the night hours, for which Dr. Serafini's register has nothing to say. In confirmation of the conclusion that the moon does not dissipate the clouds, another result from the Vigevano weather register is cited, namely, that the greatest number of rainy days happens near full moon. This result is opposed to that derived from the observations of Schubler, Bouvard, and Eisenlohr.

The value to be given to observations of the number of rainy days must evidently depend on whether the observations include the rainy nights; and an investigation on this question, to have any considerable weight, should depend rather on the measured rainfall than on the term "rainy day," for which no distinct definition is given.

The great objection to M. Faye's conclusions, as far as the facts go, is to be found in their entire dependence on the Vigevano weather register (da mane a sera). No notice is taken of other observations and results showing a lunar action on our atmosphere, such as those already mentioned, which Arago considered incontestable, those of Madler and Kreil, and the more recent investi-

gations of Mr. Park Harrison and Prof. Balfour Stewart. All of these, and many others, must be carefully considered before we can accept the conclusion that the moon has no influence on our atmosphere. The subject is, however, too large to be entered into here at present, and it will be possible to study it better after other conclusions of the learned French Academician have been examined.

There is, however, a part of the argument, whatever the results obtained may say, which merits particular consideration; and that is, that the moon's heat cannot produce the phenomena in question. M. Faye shows that if the moon's reflected heat is in the same proportion as the reflected light, such heat cannot produce a change of temperature of a thousandth of a degree Fahrenheit. I would remark that Lord Rosse's carefully-made experiments with the most delicate apparatus have shown for the total heat radiated and reflected, nearly ten times the proportion given by the reflected light; but, as M. Faye observes, if the proportion were increased a hundredfold the effect would still be insensible. "How then, " it is added, "can we expect such an action to dissipate the clouds when that of the sun does not always succeed?"

If, however, we can establish that real lunar actions exist which cannot be explained by the moon's heat reflected or radiated, the only philosophical conclusion will be that the moon must act in some other way, which it will be in the interests of science to seek out.

GWS-011 THE MOON AND WEATHER

Anonymous; Nature, 49:275, January 18, 1894.

The solitary observable effect of the moon on our atmosphere was believed by Sir J. Herschel to be exhibited in the tendency of clouds to disappear under a Full Moon. He attributed this to the heat radiated from the lunar surface. Humboldt speaks of this connection as well-known in South America, and Arago indirectly supports the theory by stating that more rain falls about the time of New Moon than at the time of Full Moon; the former period being cloudy, and the latter cloudless, according to theory. With the idea of obtaining information upon the matter, the Rev. S. J. Johnson has examined the state of the sky at moonrise and at midnight on the day of Full Moon only for the last fifteen years. His results were communicated to the Royal Astronomical Society on January 12, and they confirm the opinion now held by almost every astronomer, viz. that the Full Moon has no effect in breaking up clouds.

GWS-012 [THE MOON'S PHASES AND THUNDERSTORMS]

Anonymous; Nature, 68:232, July 9, 1903.

Pickering (referred to below) had some radical notions for his time, and it is interesting to note his willingness to accept a "third" lunar force.

Evidence of a connection between the occurrence of thunderstorms and the moon's age has been referred to in Nature on several occasions. Prof. W. H. Pickering gives a table in Popular Astronomy to show the results of investigations of this relationship by various observers. From this table, which is

abridged below, it will be seen that, with one exception, the number of thunderstorms occurring near the first two phases of the moon is greater than the number occurring near the last two.

The Moon's Phases and Thunderstorms.

Station	Authority	Years	New and First Qtr.	Full and Last Qtr.
Kremsmunster	Wagner	86	54	46
Aix la Chapelle	Pohs	60	54	46
Batavia, Java	Vand. Stok	9	52	48
Gotha	Lendicke	9	73	27
Germany	Koppen	5	56	44
Glatz County	Richter	8	62	38
N. America	Hazen	1	57	43
Prague	Gruss	20	51	49
	"	20	53	47
Gottingen	Meyer	24	54	46
Greenwich	MacDowall	13	54	46
Madrid	Ventatasta	20	52	48
Providence. R.I.	Seagrave	6	49	51

Prof. Pickering adds:—"The number of observations here collected seems to be large enough to enable us to draw definite conclusions, without fear that further records will rivise or neutralise them. From these observations we conclude that there really is a greater number of thunderstorms during the first half of the lunar month than during the last half, also that the liability to storms is greatest between new moon and the first quarter, and least between full moon and last quarter. Also we may add that while theoretically very interesting, the difference is not large enough to be of any practical consequence. Thus it would seem that, besides the tides and certain magnetic disturbances, there is a third influence that we must in future attribute to the moon. "

GWS-013 THE MOON AND WET DAYS

MacDowall, Alex. B.; Nature, 64:424-425, August 29, 1901.

Though it is counted heresy in some quarters to associate weather with the moon, the following results of a recent inquiry into the subject, whether held to be proof of lunar influence or not, might, I think, be of interest to many.

The period considered is the last 24 years. The data (which are for Greenwich) are these:-

(A) Days with .5 in. of rain, or more, in the year.

(B) Days with .4 in., or more, in the summer half (April to September).

(C) Days with .2 in., or more, in the summer half.

The method in each case was first to ascertain the distribution in seven days about each of the four lunar phases (i. e. how often each of those 28 days had rain amounting, e.g., to .5 in., or more), then smooth the series with averages of three.

Both smoothed and unsmoothed curves are given in the case of A; but only the smoothed curves for B and C.

From the fact that four weeks does not quite cover the time of a synodical revolution of the moon (which is about 29-1/2 days), there are a few wet days

in each class not coming under any of the above categories. These may perhaps, with regard to the purpose of the inquiry, be left out of account. The totals dealt with are: A, 182 days; B, 158; and C, 433. These come short of the actual totals by A, 7 days; B, 8; C, 28.

Turning now to the curves, the recurrence of four long waves in the smoothed curve for A (less pronounced in C and B), may be noted, in passing, as a remarkable feature.

All the smoothed curves agree in presenting a minimum between the full moon and the last quarter (the third, second, or first day before last quarter). As to the maximum, it is about new moon in A and B, the first quarter being not much below; but in C the first quarter comes into prominence.

The salient facts of A might be put in this way. If all the wet days (182) were uniformly distributed throughout the four weeks, each group of three days would have about 20 cases of that degree of wetness (. 5 in. or more). Now the lowest group (about the day before last quarter) has 8, and the highest (say about new moon) has 29, or nearly four times as many. The corresponding numbers for B are: av. 17, min. 10, max. 25; and for C, av. 46, min. 36, max. 58. The contrast becomes less marked as we lower the limit.

Individual days have some interesting features. Thus the third day before the last quarter has never, in these 24 years (summer half) had as much as . 4 in. of rain; and last quarter day has had such only once.

The data of Class A were further dealt with in this way. The odd years were treated as one group, and the even years as another. Both agreed in giving a minimum between full moon and last quarter. The maxima were about new moon in one case, and about first quarter in another.

In view of the present position of the moon-and-weather question, I content myself with merely giving these facts and inviting criticism.

It might happen that another 24 years would obliterate those distinctions, putting others in their place. Should the same relations continue in future, it would appear that in the few days before last quarter we have the best chance of escaping days which would be considered thoroughly wet.

GWS-014 THE MOON'S PHASES AND THUNDERSTORMS

Bianco, Ottavio Z. ; Nature, 68:296, July 30, 1903.

In connection with the note in Nature (July 9, p. 232), it is interesting to compare the results of Prof. W. H. Pickering with those obtained by Schiaparelli in 1868, from the discussion of observations made in Vigevano (north Italy) for thirty-eight years (1827-1864) by Dr. Siro Serafini.

"Although the figures of the second column show great irregularities in their proceeding, it seems nevertheless undoubted that in the first half of a lunation thunderstorms may be,generally speaking, less frequent than in the second. Adding 5 by 5 in order to see better the law of progression, one remarks that the minimum falls towards the 5th day of the lunation and the maximum towards the 24th. The ratio of the least frequency to the greatest is that of 101:153, or almost exactly of 2:3. " (Clima di Vigevano: Milano VallardL, 1868, p. 81.)

The conclusion is thus exactly the reverse of what Prof. W. H. Pickering has found.

GWT-001 ON THE CAUSES OF THE TORNADO OR WATERSPOUT

Hare, R.; American Journal of Science, 1:32:153-161, 1837.

Hare's paper is of historical interest but contains little that is really strange. After reviewing the properties of tornadoes and waterspouts, he theorizes thus.

> After maturely considering all the facts, I am led to suggest that a tornado is the effect of an electrified current of air, superseding the more usual means of discharge between the earth and clouds in those sparks or flashes which are called lightning. I conceive that the inevitable effect of such a current would be counteract within its sphere the pressure of the atmosphere, and thus enable this fluid, in obedience to its elasticity, to rush into the rarer medium above, (p. 154)

Hare elaborates in the following paper.

GWT-002 ON TORNADOS AS AN ELECTRICAL STORM

Hare, R.; Journal of the Franklin Institute, 54:28-39, 1852.

From this long rambling article, which attempts to show that tornadoes are electrical in nature, only a few eyewitness accounts and key observations have been reproduced below.

> This rationale of the tornado had been in the hands of the academicians and the library of the Academy for about three years, when, agreeably to an article published at Paris, on July 17th, 1839, in the Journal des Debats, a tremendous tornado occurred about the last of the preceding month, at Chatenay, in the vicinity of that metropolis. The losers applied for indemnity to certain insurers, who objected to pay on the plea that the policies were against thunder storms, not against tornados. This led to an application to the celebrated Arago, who referred the case to another savant, Peltier, as above stated.
>
> From the following narrative, translated from his report, it will be seen that Peltier adopted my opinion, that a tornado is the effect of an electrical discharge.
>
> "Early in the morning a thunder cloud arose to the south of Chatenay, and moved at about ten o'clock over the valley between the hills of Chatenay and those of Ecouen, The cloud having extended itself over the valley, appeared stationary, and about to pass away to the west. Some thunder was heard, but nothing remarkable was noticed, when about midday, a second thunder storm, coming also from the south, and moving with rapidity, advanced towards the same plain of Chatenay. Having arrived at the extremity of the plain above Fontenay, opposite to the first mentioned thunder cloud, which occupied a higher part of the atmosphere, it stopped at a little distance.
>
> "Up to this time there had been thunder continually rumbling within the second thunder cloud, when suddenly an under portion of this cloud descending and entering into communication with the earth, the thunder ceased. A prodigious attractive power was exerted forthwith, all the dust and other light bodies which covered the surface of the earth mounted towards the apex of the cone formed by the cloud. A rumbling thunder was continually heard. Small clouds wheeled about the inverted cone, rising and descending with rapidity. An intelligent spectator, M. Dutour, who was admirably placed for observation, saw the column formed by the tornado terminated at its lower extremity by a

cap of fire while this was not seen by a shepherd, Oliver, who was on the very spot, but enveloped in a cloud of dust.

"To the south-east of the tornado, on the side exposed to it, the trees were shattered, while those on the other side of it, preserved their sap and verdure. The portion attacked appeared to have experienced a radical change, while the rest were not affected.

"Finally, it advanced to the park of the castle of Chatenay, overthrowing every thing in its path. On entering this park, which is at the summit of a hill, It desolated one of the most agreeable residences in the neighborhood of Paris. All the finest trees were uprooted, the youngest only, which were without the tornado, having escaped. The walls were blown down, the roofs and chimneys of the castle and farm house carried away, and branches, tiles, and other movable bodies, were thrown to a distance of more than five hundred yards. Descending the hill towards the north, the tornado stopped over a pond, killed the fish, overthrew the trees, withering their leaves, and then proceeded slowly along an avenue of willows, the roots of which entered the water, and being during this part of its progress much diminished in size and force, it proceeded slowly over a plain, and finally, at the distance of more than a thousand yards from Chatenay, divided into two parts, one of which disappeared in the clouds, the other in the ground."

"In this hasty account I have, with the intention of returning to this portion of the subject, omitted to speak particularly of its effect upon trees. All those which came within the influence of the tornado, presented the same aspect; their sap was vaporized, and their igneous fibres had become as dry as if kept for forty-eight hours in a furnace heated to ninety degrees above the boiling point. Evidently there was a great mass of vapor instantaneously formed, which could only make its escape by bursting the tree in every direction; and as wood has less cohesion in a longitudinal than in a transverse direction, these trees were all, throughout one portion of their trunk, cloven into laths. Many trees attest, by their condition, that they served as conductors to continual discharges of electricity, and that the high temperature produced by this passage of the electric fluid, instantly vaporized all the moisture which they contained, and that this instantaneous vaporization burst all the trees open in the direction of their length, until the wood, dried up and split, had become unable to resist the force of the wind which accompanied the tornado. In contemplating the rise and progress of this phenomenon, we see the conversion of an ordinary thunder just into a tornado; we behold two masses of clouds opposed to each other, of which the upper one, in consequence of the repulsion of the similar electricities with which both are charged, repelling the lower towards the ground, the clouds of the other descending and communicating with the earth by clouds of dust and by the trees. This communication once formed, the thunder immediately ceases, and the discharges of electricity take place by means of the clouds, which have thus descended, and the trees. These trees, traversed by the electricity, have their temperature, in consequence, raised to such a point that their sap is vaporized, and their fibres sundered by its effort to escape. Flashes, and fiery balls, and sparks accompanying the tornado, a smell of sulphur remains for several days in the houses, in which the curtains are found discolored. Every thing proves that the tornado is nothing else than a conductor formed of the clouds, which serves as a passage for a continual discharge of electricity from those above, and that the difference between an ordinary thunder storm and one accompanied by a tornado, consists in the presence of a conductor of clouds, which . seem to maintain the combat between the upper portion of the tornado and the ground beneath." (pp. 30-32)

To conclude, I claim to have laid before the scientific world a memoir, in which the tornado is made to bear the same relative position to lightning that the carrying discharge does to the electrical spark, and to have been the first electrician that ever pointed out this simple and true relation between those awful meteors. I urge that the language, proceedings, and reports of the French academicians show, that they were entirely unprepared for this new view of the subject. Hence, nearly five years afterwards, notwithstanding the tornado at Chatenay and Peltier's Report, and that I had sent them meanwhile a pamphlet containing a translation of my memoir into their own language, they still remained in utter darkness: but that meanwhile, Peltier, with the approbation of Arago, the President of the Academy, had adopted essentially my explanation; attempting, however, to put my theory in the back-ground, by substituting conduction for convection.

As I have elsewhere said, Franklin by aid of a kite-string demonstrated the identity of lightning with the electrical spark or diruptive discharge. I hope to have shown, by reasoning and a reference to experimental evidence, that the tornado is identical with the convective discharge of electricity, (p. 35)

GWT-003 ON WATER-SPOUTS

Oersted, Hans C.; American Journal of Science, 1:37:250-267, 1839.

Sound and Smell of Water-Spouts.——Water-spouts are often accompanied by a violent noise, which, for the most part, has been compared to the sound of many heavily laden waggons moving over a stone pavement, or to the breaking of the waves of an agitated sea against the coast; but, by some, has been said to resemble the roar of a great waterfall. Besides these great noises, a whistling or piping sound has not unfrequently been heard.

Water-spouts often leave behind a sulphureous smell, and there are examples of a disagreeable smell remaining along the whole tract traversed by them. One individual, however, who became involved in a water-spout, perceived no odor. (p. 256)

We seldom read accounts of water-spouts without finding also that electrical phenomena were noticed at the same time. Lightning is almost never wanting; thunder is likewise often connected with them, and it has been remarked that the loud noise which follows water-spouts easily prevents feeble peals of thunder from being heard. Now and then, a more widely dispersed light has been seen; so that people imagined that the corn in the fields was on fire, but afterwards to their joyful astonishment found it uninjured. It has been reported of one water-spout that fire balls proceeded from it, of which one was accompanied by a report like that of a musket. Probably, however, in this instance, electric sparks caused a deception. Frequently, great storms follow the occurrence of water-spouts; sometimes they precede them. (p. 257)

Inherent in the above discussion are several electric discharge phenomena which resemble those perceived during earthquakes and other geophysical phenomena.

GWT-004 A REMARKABLE WIND STORM

Anonymous; Scientific American, 48:336, June 2, 1883.

GWT-005 TORNADOES AND WATERSPOUTS

A storm, or a series of storms, of high wind, rain, thunder, and lightning swept over portions of northern Texas, Nebraska, Missouri, Illinois, and Wisconsin, May 17 and 18, destroying property and lives, and making waste the country in its path. In some places this path was only 300 yards wide, in others it covered a width of one-fourth of a mile, and in other places extended to a width of two miles and more. No structure of man withstood the blast within its well defined limits; substantial buildings of brick and lighter buildings of wooden framework alike succumbed to the gale that accompanied the storm. In some localities the storm assumed a whirling motion, but in most places it appeared to be a straight-away gale. Unlike the poputar idea of a tornado, which is that it comes suddenly after an apparent elemental slumber, this storm appeared to be the culmination of a severe rain and thunder storm. And yet there were indications of a peculiar electrical activity. Globes of fire were observed in the midst of dark clouds; a well defined hole was made in a roof as if cleanly cut; the top story of a brick dwelling was carried away, while the remaining portion of the house remained untouched.

GWT-005 [TORNADO HEATING EFFECTS]

Anonymous; Nature, 44:112, June 4, 1891.

The paper summarized below was read before the French Meteorological Society.

M. Teisserenc de Bort communicated the results of his inquiries respecting a destructive tornado which visited the town of Dreux on August 18 last. At lOh. 5m. p.m., Paris time, a sharp clap of thunder occurred, followed by heavy rain and hail for about a minute, and five minutes later the tornado broke over the town with a noise resembling that of an express train, making a furrow in the ground, and in less than a minute tiles were flying about, trees uprooted, and several houses destroyed. After a short course the effects of the tornado ceased, and it appeared to rise to the upper strata of air, but descended again with equal violence near Epone about 60 kilometres distant, the rate of translation being about 29 miles an hour. The action of the electricity seemed to be of an unusual nature; although much damage was done by it, no metallic object was fused, but only traces of fusion could be found in bad conducting bodies. Among other incidents an iron bedstead was dismounted, without trace of fusion. The paper was illustrated by several photographs, showing the damage done in various parts of its path.

GWT-006 THE TORNADO OF MONVILLE

Zurcher, Frederic; Meteors, Aerolites, Storms, and Atmospheric Phenomena, C. Scribner & Co., New York, 1876.

. . . . . However, there was no tornado as yet, properly speaking; but, after receding to a distance and traversing some twenty-five miles, the storm suddenly returned into the valley near Malaunay and Monville, passing through a wood, the trees in which it broke off close to the ground. At that moment, an enormous cone, of sharply defined outline and as black as coal-smoke, was seen to assume shape. The top of it was of a reddish-yellow, while it emitted

flashes of lightning and a heavy rumbling sound. In a few seconds, the tornado hurled itself, with appalling velocity and by zigzag motion, through three considerable spinning-mills in succession, crushing them and all the working-people in them. The roofs were swept off, and not one stone left on another. The looms were twisted, the heavy pieces shattered, chiefly, too, where there were ponderous masses of metal. The trees in the vicinity were flung down in every direction, riven and dried up for a length of from six to twenty feet and more. While clearing away the ruins, in the attempt to rescue the unfortunate people buried beneath them, it was noticed that the bricks were burning hot. Planks were found completely charred, and cotton burned and scorched, and many pieces of iron and steel were magnetized. Some of the corpses showed traces of burning, and others had no visible cuts or contusions, but seemed to have been killed by lightning. Workmen who were hurled into the surrounding fields, all agreed in saying that they had seen vivid flashes and had noticed a strong smell of sulphur. Persons who happened to be on the adjacent heights, alleged that they saw the factories wrapped in flames and smoke as the cloud enveloped it. The breadth of the belt laid waste by the tornado was seven hundred and fifteen feet on the level of Malaunay, less than one and a half miles from the point where its ravages began, nine hundred and ninety-five feet in the middle, and one hundred and ninety-five feet near Cleres, where the cloud disappeared. The length of the belt, as the bird flies, was about ten miles.

"One really very remarkable circumstance is, that debris of all kinds, such as slate, glass, planking, and pieces of wood-work, mingled with cotton, fell near Dieppe, at a distance of from fifteen to twenty-three miles from the scene of the catastrophe. These various objects were beheld in the air by several persons, who mistook them for the leaves of trees, so high were they above the ground. Among the scattered fragments carried thus far, was a scantling more than a yard long, five inches wide, and half an inch thick, (pp. 154-155)

The heating and burning effects are of especial interest, for they may indicate electrical or other forces at work.

GWT-007 WATERSPOUT

Anonymous; Monthly Weather Review, 28:115, March 1900.

The schooner Metha Nelson, which arrived February 19 at San Francisco, Cal., from Makaweli, Kauai, Hawaiian Islands, encountered a waterspout on Sunday February 18, when 30 miles northwest of Point Reyes. Captain Rice states that:

On Sunday morning his vessel was pursued by a column of water which emitted flashes of lightning, and was preceded by a thin curling sea. The weather for the preceding twenty-four hours had been a succession of rain squalls, but the sea was moderate and the weather not unusual for this time of the year.

When the spout first appeared it was some distance astern, according to an account given by the mate, and apparently bearing directly down upon the schooner. There was just time to make everything fast when the great swirling mass of water was close astern and towering over the little vessel. Then, by some strange good fortune, it suddenly changed its course and swept by, only catching the spanker boom and carrying it away. The schooner was thrown on her beam ends by the disturbance of the water but soon righted herself and continued on her course.

GWT-008 TORNADOES AND WATERSPOUTS

GWT-008 FREAKS OF THE TORNADO

Walsh, George E.; Harper's Weekly, 57:25, May 17, 1913.

The Weather Bureau at Washington has been collecting statistics and facts about cyclones and tornadoes for many years, and the experts have succeeded in securing considerable valuable data about the big winds; but, after all, the freaks of the storm are the things that give it special interest, and if all these were properly classified some remarkable reading would be furnished. Every visitation of a tornado adds to this valuable storehouse of queer freaks.

It is not uncommon for the whirling wind to cut a house in half, demolishing one side and leaving the other undisturbed. This happened in an Iowa tornado, and the part that was left intact was so little disturbed that the clock on the mantel continued ticking as if nothing had happened. In the Texas town of Sherman, which was visited by a tornado in 1896, two houses were picked up and carried into the air, where they exploded. Every one in them was severely injured except a baby, which did not receive so much as a scratch. A man milking a cow in a shed saw the cow and shed carried up in the air, but he was not so much as touched. Not a drop of the milk in his pail was spilled or disturbed.

In the St. Louis tornado of the same year a carpet in the parlor of one house was pulled up by the twister and carried away a few hundred yards without so much as a rent being torn in it. The tacks had been pulled up as neatly as if extracted by a careful carpet-layer. In another house the bed-clothing and mattress were lifted from the bed, and the bedstead was left intact. A resident was carried through the roof of another house with the bed and dropped a quarter of a mile away without injury. The mattress saved him in the fall, and he picked himself up in a vacant lot to dress without knowing exactly what had happened to him.

The "twisters" have been known to pull nails out of shingles and then go on to pick up a chimney bodily and carry it through the air. In Kansas one picked up a buggy and landed it in the branches of a tree. At another time it ripped the harness completely off a horse and left horse, buggy, and man uninjured. In Louisville in 1890, a tornado carried the roof off a house and pulled a child from the mother's arms and carried it safely to another house six blocks away.

But these are merely among the harmless freaks of the big wind. There are others more heartrendering. It has dismembered human beings, tearing arms and legs from the body, and twisted the hair of women into ropes. In Kansas it drove a piece of scantling six inches square through the body of a hog. At another time it blew in the door of a farmer's house and carried the owner away on the door, to drop him in the branches of a tree. The tornado did not hurt him, but he broke his neck falling from the tree to the ground. No one has succeeded in measuring the full force of a tornado, but it is known to travel at the rate of two hundred miles and more an hour.

Tornadoes are exciting more general attention than formerly because of the greater number of towns and villages located in the tornado belt. Each successive one is more dangerous than its predecessors because it is apt to find more human material to destroy. Formerly it might travel half the length of a continent without finding anything in its path to destroy except grass, trees, and occasionally the crops of a solitary farmer. To-day, if it followed the same route, it might pass over a dozen villages and towns.

The only thing that can possibly break the force of a tornado is a range of mountains. It may create wild havoc among the trees and boulders of a mountain, but it cannot carry the mountain itself away. It will uproot giant forest trees, suck the water from wells and streams, twist and demolish iron bridges,

and carry up houses, but the mountains are proof against the mighty force of the wind. Until we know how to control the tornado or find some means of baffling it, its menacing danger must always be a source of considerable uneasiness in the great plain sections of the country. But, like earthquakes, the tornado and cyclone do not come every year, and sometimes they defer their visit for a decade or so, for which we may be thankful.

GWT-009 AN ELECTROMAGNETIC BASIS FOR THE INITIATION OF A TORNADO

Rathbun, E. R.; Journal of Meteorology, 17:371-373, June 1960.

A major point brought out in this long theoretical treatment is that the earth's magnetic field can add a spiral motion to charged particles, thus setting up the characteristic "twister" action of the tornado.

GWT-010 THE TORNADO

Anonymous; Nature, 54:104-105, June 4, 1896.

Following some generalities about tornadoes, we come to the unusual phenomena accompanying the destructive St. Louis tornado.

> The weather at St. Louis nearly the whole of Wednesday, May 27, was unusually warm and oppressive. There was not a breath of wind, and the people suffered greatly from the heat. About four o'clock in the afternoon the western horizon became banked with clouds piled one on top of the other, with curling edges tinged with yellow. The sight was beautiful, but somewhat terrifying. Then a light wind sprang up, followed by sudden and ominous darkness.
>
> The gloom deepened, and when the storm actually burst upon the city pitch darkness prevailed. These strange atmospheric disturbances had created anxiety among the people abroad in the streets, but not alarm.
>
> There seemed to be three separate and distinct storms. They came from the north-west, from the west, and from the south-west, but when these reached the river they had become one.
>
> Before the great mass of menacing clouds which were hanging over the villages of Clayton, Fernridge, Eden, and Central gave forth their contents funnel-shaped formations shot out of them. Some of these funnels seemed to be projected into the air; others leaped to the earth, twisting and turning like some wounded monsters. Lightning played about them. There was in fact, a marvellous electrical display. Then came the stupendous outburst.
>
> From the great black clouds came a strange, weird, crackling sound, at times stronger than the incessant peals of thunder which had from the first been a terrifying feature of the storm. The funnels enveloped the western side of the city, and within thirty minutes of their first appearance on the horizon they were dealing out destruction.

GWT-011 TORNADOES AND WATERSPOUTS

GWT-011 AN INCIPIENT TORNADO IN IOWA

Anonymous; Monthly Weather Review. 31:282-283, June 1903.

Mr. Charles A. Robertson, of Onawa, Monona County, Iowa, staff correspondent of the Sioux City Tribune, furnishes an account of a whirlwind in the eastern part of Monona County, between 5:15 and 5:30 p. m. Friday, June 26, 1903. He says:

A great mass of black clouds was gathering, and on the western edge of a rift in the clouds were plainly to be seen two strange objects. In the north and west the sky was clear and the sun was shining, while in the southeast, for fully half an hour, the queer long-tailed specters wavered in the air, moving in a general way southerly. Suddenly the long tail of the larger whirl seemed to part from the upper funnel-shaped mass and descend to the ground like a long thin waterspout while a faint light appeared between the upper and lower portions. Telephone messages afterwards received from points to the southeast, such as Moorhead, distant 15 miles, and from Ute, which is 20 miles east of Onowa, and from Blencoe, 8 miles south, state that the waterspouts, whirlwinds, or tornadoes were seen by all, causing much uneasiness, but no damage was experienced, and also that for a long time, one of the two threatening clouds remained stationary over a lake about 3 miles southeast of Turin, which is itself 7 miles east of Onawa, and that it drew a supply of water up from the lake, sucking up also, fish, frogs, worms, and vegetable matter, all of which were afterwards dropped back in that locality.

GWT-012 THE ROLE OF ELECTRICAL PHENOMENA ASSOCIATED WITH TORNADOES

Wilkins, E. M.; Journal of Geophysical Research, 69:2435-2447, June 15, 1964.

Abstract. Laboratory model vortex experiments and theoretical investigations were conducted to determine whether the unusual electrical phenomena which sometimes accompany a tornado might play an important role in the life cycle of the tornado. The electrodynamic accelerations of ions appear unimportant in either the formative or mature stages. Heat released by lightning may serve to initiate updrafts, but the effectiveness in tornado formation is difficult to evaluate in the presence of the latent heat available in a convectively unstable atmosphere. Laboratory experiments indicate that a more or less continuous electrical discharge in the center of a vigorous aerodynamic vortex will inhibit rather than augment the vortex circulation.

GWW-005 SINGULAR PHENOMENON

Anonymous; London Times, July 5, 1842.

> Wednesday forenoon [June 29] a phenomenon of most rare and extraordinary character was observed in the immediate neighborhood of Cupar. About half past 12 o'clock, whilst the sky was clear, and the air, as it had been throughout the morning, perfectly calm, a girl employed in tramping clothes in a tub in the piece of ground above the town called the common, heard a loud and sharp report overhead, succeeded by a gust of wind of most extraordinary behemence, and only of a few moments duration. On looking round, she observed the whole of the clothes, sheets, &c. lying within a line of certain breadth, stretching across the green, several hundred yards distant; another portion of the articles, however, consisting of a quantity of curtains, and a number of smaller articles, were carried upwards to an immense height, so as to be almost lost to the eye, and gradually disappeared altogether from sight in a south-eastern direction and have not yet been heard of. At the moment of the report which preceeded the wind, the cattle in the neighboring meadow were observed running about in an affrighted state, and for some time afterwards they continued cowering together in evident terror. The violence of the wind was such that a woman, who at the time was holding a blanket, found herself unable to retain it in fear of being carried along with it! It is remarkable that, while even the heaviest articles were being stripped off a belt, as it were, running across the green, and while the loops of several sheets which were pinned down and snapped, light articles lying loose on both sides of the holt were never moved from their position.——Fife Herald.

This is the complete quotation from the Times as referred to in GWW-003. See this entry for a comment about the detonation. The action of the whirlwind, if that is what it was, reveals the prankish character frequently noticed.

GWW-006 NOTES ON LOCAL WHIRLWINDS IN NEW BRUNSWICK

Kain, Samuel W.; Monthly Weather Review, 28:488-489, November 1900.

The following incident occurred at 4 P. M., May 24, 1900, and was reported by Keith A. Barber.

> While Mr. Barber was standing by the side of a pool of water about six miles from Clarendon Station, Charlotte County, he heard in the distance a shrieking whistling sound; this continued to increase in intensity, and turning to seek a cause he noticed a whirlwind advancing from the hills, its course indicated by the swaying shrubs and a noise somewhat like that produced by a express train, but not so loud. It struck the pool about three feet from the shore and raised the water in a foaming mass of froth and spume to a height of 5 feet, and crossing threw the water upon the farther shore. Its path across the pool was about *15 feet wide. Mr. Barber was standing about one hundred feet from the path of the whirlwind. The sky was clear all day. In the morning there were a few light clouds, but after 2 p.m. the sky was cloudless.

The wind was northeast till noon, then shifted to southwest and south. It was light all day. The barometer was steady; at 8 a.m., 30.081; at 2 p.m., 30.129; at 8 p.m., 30.185. In St. John the highest temperature was 65°F., but at Clarendon the temperature was probably about 5° higher, the preceding days had been cold, and the change in temperature was considerable and rapid.

A very similar phenomenon was observed on Wednesday, June 14, at Grassy Lake, Kings County.

Dr. Colter, post office inspector, and Mr. Richard Magee, of the railway mail service, were fishing from a moored boat on the lake. It was a fine, clear day, and a good breeze was blowing when about 2 o'clock in the afternoon they heard a roaring in the woods, and with a rushing noise a few hundred feet from them the water of the lake commingled with reeds, lillies, and mud was torn up and hurled into the air, forming a waterspout apparently about 30 feet in diameter.

It lasted about two minutes, and for about that time the air seemed somewhat darkened. The violence of the wind drew their boat from its moorings in among the reeds, and it was fortunate that they were far enough from the path of the whirlwind to escape any more serious results.

GWW-007 METEOROLOGICAL PHENOMENON

Galton, Francis; Nature, 44:294, July 30, 1891.

I have received in a letter from a friend residing in Boraston, Shropshire, the following accounc of a remarkably interesting meteorological phenomenon, which is well worth putting on record:-

"We had a curious sight from this house yesterday [July 26]. It was a dead calm, but in a field just below the garden, with only one hedge between us and it, the hay was whirled up high into the sky, a column connecting above and below, and in the course of the evening we found great patches of hay raining down all over the surrounding meadows and our garden. It kept falling quite four hours after the affair. There was not a breath of air stirring as far as we could see, except in that one spot."

Again we have very narrow localization of whirlwind action; also a prankish element. Other hay falls are presented in GFL.

GWW-008 [LEVITATED HAYSTACK]

Russell, Eric F.; The Fortean Society Magazine, 1:8, January 1940.

Men loading hay at Eastwood, Tarrington, Hereford, were astonished to see one haystack rise "slowly" in the air to a height of 20 feet or more. "It remained in the air steady and intact for several seconds then dispersed slowly (sic) over the field." London Mirror, 8-17-39.

SUBJECT INDEX

All indexes in this volume apply to both volumes G1 and G2. Subsequent volumes in the STRANGE PHENOMENA series will be self-contained with cumulative indexes available separately to those who wish them.

Proper names are so profuse in the sourcebooks that a thorough index of them would overwhelm the book. Therefore, only the most important proper names, such as "Barisal Guns" and "Hornet Light", are indexed.

SUBJECT INDEX

DATE-OF-EVENT INDEX

Note that the three-letter prefix provides a substantial clue as to the type of phenomenon.

The literature has only been scratched, and the dates below do not represent a valid distribution of anomalous events. The heavy use of Nature prior to 1900 accounts for the many dates in the late 1800s.

DATE-OF-EVENT INDEX

DATE-OF-EVENT INDEX

DATE-OF-EVENT INDEX

PLACE-OF-EVENT INDEX

Many place names in the accounts reproduced in the volume are rather obscure, particularly if the accounts are old ones when geographical names were often different from today's. Therefore, place names are first categorized by major geographical regions: the continents and oceanic areas, Central America, the Middle East and Asia Minor, etc. United States references employ the standard two-letter state abbreviations. As with the other idexes, the content of an entry can be gleaned from the three-letter prefix.

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