
SIGILLVM ✠ ACADEMIÆ : HARVARDIANÆ : IN : NOV : ANG :
CHRISTO ET ECCLESIÆ

# METEORS, AEROLITES,

AND

# FALLING STARS.

*Sæpe etiam stellas, vento impendente, videbis*
*Præcipitas cœlo labi, noctisque per umbram*
*Flammarum longos a tergo albescere tractus.*

VIRGIL. GEORG. I.

VINCENT BROOKS, LITH

FIG. 17. THE ZODIACAL LIGHT AS SEEN BY THE AUTHOR FROM PUTNEY ON THE 24TH MARCH 1866, AT ½ PAST 7. P.M.

# METEORS, AEROLITES,

AND

# FALLING STARS.

BY


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TO

# M. A. DAUBRÉE,

MEMBER OF THE INSTITUTE (ACADÉMIE DES SCIENCES),
PROFESSOR OF GEOLOGY IN THE MUSEUM OF THE JARDIN DES PLANTES, PARIS, ETC. ETC.

*Dear Sir,*

*I inscribe this little Work to you, though it is a mere outline of the magnificent subject it pretends to treat, as a slight proof of the esteem and admiration in which I hold your most valuable researches in Chemistry and Geology.*

*Faithfully yours,*

*THE AUTHOR.*

# PREFACE.

In the present work I propose to write the natural history of *falling stars* in the widest acceptation of the term. I have taken for model the justly celebrated little work of François Arago, entitled 'Notice sur le Tonnerre,' in which that elegant writer made popular everything that is known concerning thunder and lightning. Before the appearance of that excellent little treatise in the pages of the 'Annuaire du Bureau des Longitudes' for the year 1838, it may be safely asserted that little or nothing was known about thunder storms among "the masses of the people." What Arago did for the grand phenomenon of lightning, I will attempt to do for a class of natural phenomena still more impressive, until recently much less observed, considerably rarer; and those, who have had the good fortune to witness in all its grandeur only one luminous meteor, will not hesitate in classing it among the most wonderful and astonishing spectacles that nature can present to us. Never was there a period more suitable than the present for laying before the public a popular exposition of this subject. After numerous and most persevering observations, carried on simultaneously in all parts of the globe, we have at last, quite recently, been placed in possession of sufficient data to clear up nearly all the mysteries that have hitherto been attached to these falling stars or aerolites, even by the most learned philosophers. And I do not think I exaggerate in the slightest degree when I assert that the minds of most men are at the present day in precisely the same unsettled, anxious, and uncertain state, with regard to the phenomena treated of in this work, that they were in with regard to thunder-storms and lightning when Arago's treatise appeared. Nay, it might perhaps be stated that at that period a greater number of observations had been collected and published relating to atmospheric electricity than we possess even now for falling stars or aerolites. But however that may be, there is a sufficient supply of facts at present to enable me to proceed at once with my task; for the more mystery attaches to a class of natural phenomena, the more persevering are man's endeavours to elucidate these phenomena, and such has certainly been the case with falling stars.

I have been at no little pains in collecting the most authentic and most striking facts connected with that class of luminous meteors commonly designated falling stars, fire-balls, aerolites, etc.; but those who would expect to find here a complete list of all the stars or stones that have fallen upon the earth since ancient times up to the present day, will be disappointed. I do not wish to produce a dry catalogue of facts more or less resembling each other, though nothing would have been easier than the formation of such a catalogue, the elements of which are now before me. But I have thought it better to extract from these numerous observations (amounting to upwards of two thousand) those which will suffice to place the reader in possession of all the facts essentially connected with our subject, and enable him to grapple with any difficulties which may yet appear to him unsolved.

The swarm of meteors which excited so much admiration on the night of the 13th of November last, will doubtless attract many persons to a subject hitherto little heeded; and those who may not have been fortunate enough to witness it will have another opportunity on the 11th, 12th, or 13th of November, 1867. To these the following pages, imperfect as they are, may not be altogether unwelcome.

THE CEDARS, PUTNEY, S.W.
*1st December*, 1866.

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# METEORS.

## CHAPTER I.

'METEORS,' 'SHOOTING STARS,' 'METEORITES,' 'FIRE-BALLS,' 'BOLIDES,' 'AEROLITES,' 'METEOROIDS,' 'FALLING STARS,' 'METEORIC STONES,' 'METEOROLITES,' 'METEORODES,' ALL ESSENTIALLY IDENTICAL.

THE heading of this chapter enumerates the various names that have been proposed in the English language to designate what might be briefly termed "falling stars." On the Continent various other appellations have been invented, such as *star-snuff* (sternschnuppen) in Germany, *astéroïdes* (little stars), *meteoric iron* (fer météorique) in France; whilst in Sweden the term *stjernjfall* (falling stars), and in Italy *stelle cadenti* (id.), corresponding to the French *étoiles filantes*, are used.

The word *aerolite* is almost universally understood, and has but one meaning, whilst the English term *luminous meteor*, so commonly applied to fire-balls or aerolites, serves also to designate a considerable number of luminous phenomena, in no way connected with shooting stars; it should therefore be used with great caution in connection with these phenomena.

If we can prove that all these various appellations apply to one and the same phenomenon seen from different points of view or in different circumstances, a great step will have already been made, and much confusion and obscurity cleared up. This will, I trust, soon appear in the course of the present work, but let me state here at once, that the term *shooting star* or *falling star* is made use of to designate that luminous stream which is seen in the evening to shoot across the clear starlit sky at certain intervals, appearing as a star which leaves its place in the firmament and is suddenly shot away, with the rapidity of the arrow from the bow, into another region of the heavens. It will be seen further on, that this phenomenon occurs at a very great height above the surface of the earth. The same may take place considerably nearer to the spot on the earth's surface occupied by the observer, when the phenomenon presents itself in another aspect. In this case it is no longer a small star that is seen to dart across the heavens, but a brilliant meteor, appearing somewhat like a ball of fire (often visible even in the clear daylight) leaving a highly luminous train behind it, and passing rapidly through the atmosphere, lighting up, at night, the entire landscape around the observer, and often accompanied by various noises. In this case the falling star is generally designated as "*a fire-ball*" (also applied to globular lightning, which is frequently described as "*a ball of fire*"), "*a meteor*" (also applied to lightning, to haloes, hail, waterspouts, etc.), or "*a bolide.*" We shall therefore look upon *falling stars* as fire-balls or bolides at a very great distance, and shall presently bring forward ample proof of the justness of this opinion. Now it happens that when these fire-balls (luminous meteors, bolides) pass within a few miles of us, a loud detonation or explosion is heard, followed by a noise like that of musketry, and certain solid substances are shot away from them and reach the surface of the earth, sometimes within a short distance of the observer, sometimes at a distance of several miles. The fragments generally penetrate a certain depth into the earth; however, they are often picked up very soon after their fall, and are then warm or even hot to the touch. To these fragments, which vary considerably in size, the name of *aerolites* (*meteorites* or *meteoric stones*) has been given when they are of a stony appearance, or *meteoric iron* when they appear to be entirely metallic. Let us state at present that whatever the external or internal appearance of the fragments thus picked up, they are always of the same composition, being composed of *rocky substance* and *metallic iron,* these two elements varying considerably in proportion one to the other, so that we have some *aerolites* in our collections which appear to be almost *entirely stony,* others almost *entirely metallic,* and others again which contain nearly *equal proportions of the metallic and stony ingredients.*

Having now defined, as nearly as possible, for the present, the value of the expressions to be made use of in this work, we will proceed to examine the phenomena of falling stars more in detail.

## CHAPTER II.

### THE ATTENTION OF SCIENTIFIC MEN DIRECTED TO AEROLITES IN COMPARATIVELY RECENT TIMES.

ALTHOUGH we have abundant evidence that aerolites have fallen upon the earth in the most ancient historic times, and that these falls have been witnessed by several ancient writers, who describe them sometimes with very great accuracy, yet it is astonishing to note how few years have elapsed since the attention of modern philosophers was first called to this interesting subject! Indeed it was not until the science of chemistry had made considerable progress, that the moderns could be induced to believe that stones fell from the sky upon the earth. It was the German philosopher Chladni, who, in 1794, first induced scientific men to investigate the subject. He published in that year a treatise* upon a large mass of iron discovered in Siberia, by a well-known naturalist, Dr. Pallas, and endeavoured to prove that *this metallic mass*, which we shall allude to again, *must have fallen from the atmosphere, and that similar masses of metal described by ancient writers must have*

* Chladni, 'Ueber den Ursprung,' etc., Riga and Leipzig, 1794; see also his other work, 'Ueber Feuer Meteore,' etc., Vienna, 1819; his "Catalogue" in Ann. de Chim. xxxi. (1826).

*had the same origin.* They were evidently not of volcanic nature; nothing like them, either in aspect or composition, is to be found in the strata of the earth; finally, certain old writers had already asserted that stones, etc., had been noticed to fall from the skies upon the earth.

Just *two months after* the publication of this remarkable treatise, a prodigious fall of aerolites occurred at Sienna, in Italy, (on the 16th June, 1794), as if destined to confirm the views brought forward by Chladni. The fall was well observed by competent authorities; about a dozen of the stones were picked up at the time, one of which was sent to Sir Joseph Banks as a curiosity. In 1796, a peculiar stone, weighing *half a hundredweight*, was exhibited in London; it was said to have fallen near Wold Cottage, in Yorkshire, on the 13th of December, 1795; and Sir J. Banks remarked that there was a very great resemblance between this stone and the one he had received from Italy (Sienna), with an account of its having fallen from the air, together with many others, in 1794. In 1799, Sir J. Banks received some other specimens of stones which were seen to fall at Benares, in Bengal, on the 19th December, 1798; and these specimens were very similar to the Yorkshire stone. In 1802, Luke Howard published a paper entitled "Experiments and Observations on certain Stony Substances which, at different times, are said to have fallen on the Earth." This paper, published in the 'Philosophical Transactions' for that year, is remarkable as containing the first chemical analysis of an aerolite that was ever made.* The observations relate to a stone which fell in

* It is singular to relate that in the biographical notice on Luke Howard, which has lately appeared in the Proceedings of the Royal Society, no mention is made of this important paper!

Portugal in 1796, and to those which fell at Sienna (1794), in Yorkshire (1795), and at Benares (1798); also to certain metallic masses from South America, etc. This paper, in which it was shown that aerolites differed from every known description of stone, both in aspect and chemical composition, cleared up all doubts in England concerning the *falling of these stones from the sky*. The analysis made by Howard of the Benares meteorite helped not a little to establish his opinion in the minds of inquirers. This, we have said, happened in 1802.

In France, however, little was yet known concerning meteorites; and in 1803, when the official notice of showers of stones at L'Aigle, in Normandy (on the 26th April, 1803), was received in Paris, it was simply laughed at, and the mayor of L'Aigle ridiculed in the public newspapers! The sensation created in England by the publication of Howard's paper and his analysis of the Benares stone, had, however, its due effect in France. Under the influence of it, the Academy of Sciences deputed the afterwards celebrated philosopher Biot to examine the subject of the fall of stones at L'Aigle on the spot. This eminent observer soon satisfied himself of the authenticity of the facts related, and published his observations in the seventh volume of the 'Mémoires de l'Institut.' *The certainty that these stones, and others, had fallen from the atmosphere* was thus established in France. Since that time, a great number of aerolites, seen to fall, have been analysed by several chemists, and their composition ascertained with the greatest care and accuracy.

Such is, in a very few words, the historical dawn of our *modern* knowledge of the fall and nature of aerolites.

But it must appear evident to any who have investigated the more ancient accounts of these natural phenomena, that in the minds of several nations of antiquity,—Chinese, Tartars, Greeks, and Romans,—the *certainty* which penetrated so slowly and with so much difficulty into Germany, England, and France, had been already acquired in the remotest historical periods. Mere hearsay, tradition, history,—call it by what name we will,—is not calculated, however, to satisfy men accustomed to deal with facts; and it is not surprising that enlightened minds, in the commencement of the nineteenth century, waited for scientific proof, before adopting the views that were so strikingly, but rather prematurely, brought forward by Chladni.

## CHAPTER III.

'FIRE-BALLS' (BOLIDES) ARE NOT THE ONLY 'METEORS' WHICH SHOW THEMSELVES AS BALLS OF FIRE; GLOBULAR LIGHTNING, 'VOLCANIC BOMBS,' ETC., EXHIBIT A SIMILAR APPEARANCE.

THE rare kind of lightning known as *globular lightning* usually shows itself in the form of a ball of fire, "about the size of a child's head;" but it is readily distinguishable from fire-ball meteors, especially by its slow motion, its proximity to the earth, etc. Globular lightning has been seen, for instance, *proceeding slowly* along a street at a *little height from the ground,* its progress not being faster than a man's ordinary walk,—in fact, carried along, as it appears, by the prevailing current of air, and finally exploding by contact with a lamp-post. It has been seen sometimes to enter a room by an open window, and to remain for a short time almost stationary, and then slowly to wend its way to the chimney, where it has made its exit, exploding with violence before reaching the outside of the house. Again, globular lightning has been more than once seen *rolling slowly* towards a ship or boat at sea, at a *slight elevation* above the water.* Nothing of the sort is seen with meteorites. They always appear at a *considerable elevation* in the atmosphere. Their motion is *very rapid,* though not so rapid as that of ordinary lightning. Globular lightning appears before or directly after heavy thunderstorms; meteorites (fire-balls, aerolites) *generally* appear in the *calmest weather,* though they have been observed during a storm,—a fact of which we have a remarkable observation in Admiral FitzRoy's 'Weather Book,' and to it I shall refer again. These circumstances enable us to distinguish readily a meteoric fire-ball from those cases of lightning appearing as falling *globes of fire,* several of which Arago has registered in his 'Notice sur le Tonnerre.' It frequently happens that when lightning is seen to strike a house or a tree, for instance, it appears as a *ball of fire which descends rapidly to the earth, followed or accompanied* by a violent peal of thunder. The phenomenon of meteorites is very similar to this, and doubtless many cases of the latter have been described as lightning; whilst it is not improbable that some cases of meteors (fire-balls, aerolites) have been mistaken for lightning.

In the thunderstorms which invariably accompany volcanic eruptions we have not only lightning, which sometimes assumes the form last noted, but also *globular masses of incandescent lava* are sometimes projected into the atmosphere, and might also be described as "fire-balls," appearing as they do like balls of fire. But these *volcanic bombs* are only observed during eruptions;

* See my 'Phosphorescence, or the Emission of Light by Minerals, Plants, and Animals,' where a most curious case of globular lightning is described; also Arago, 'Notice sur le Tonnerre,' in his 'Œuvres Complètes;' and Babinet in the journal 'Cosmos,' vol. i., Paris, 1852.

they fall in a parabolic curve to the earth, after having been shot up to a certain distance in the air, and bear little resemblance to the phenomenon of meteoric fire-balls or aerolites. These bombs are moreover never thrown higher than about 8000 feet, whilst aerolites appear considerably higher.

That these volcanic bombs do sometimes resemble, in a most remarkable manner, those fire-ball meteors which threw down aerolites, will be seen by the two observations of bombs of this kind alluded to by Sir William Hamilton in his well-known 'Account of the Eruption of Vesuvius' in the summer of 1794. He says, "The day in which Naples was in the greatest danger from volcanic clouds, *two small balls of fire joined together by a small link like a chain shot* [exactly what appeared with the aerolite which fell at Agram] fell close to my casino at Pausilippo; they separated, and one fell in the vineyard above the house, and the other in the sea, so close to it that I heard the splash in the water." (Phil. Trans. 1795.) It is to be regretted that a specimen of this stone was not collected; but at that period aerolites were scarcely known at all. It is curious to note that the celebrated fall of aerolites at Sienna, in Tuscany, 250 miles distant only, occurred at precisely the same time. "The Abbé Tata," continues Sir William Hamilton, "in his printed accounts of this eruption, mentions an *enormous ball of fire* which *flew out of the crater* of Vesuvius, while he was standing on the edge of it, and which *burst in the air at some distance* from the mountain, soon after which he heard *a noise like the fall of a number of stones*, or of a heavy shower of hail. Such observations as the above, doubtless, led Laplace and others to conjecture that fire-ball meteors (aerolites) originated in lunar volcanoes.

# CHAPTER IV.

## APPEARANCES PRESENTED BY FIRE-BALL METEORS TO AN ORDINARY OBSERVER.

The preceding remarks suffice to show the necessity of having a clear notion of the manner in which meteoric fire-balls present themselves to an ordinary observer. And it may be noted here, that their appearance differs considerably, according to the position occupied by the observer in reference to their course. Firstly, if the meteor advance directly towards him, or proceed directly from him, it appears for some moments as a *stationary* ball of fire, after which it will generally move rapidly to the right or to the left, and after some time is often seen to explode; the explosion in some cases is followed by one or more detonations in the air. Secondly, if the observer be situated near the centre of the arc described by the meteor, and views the latter sideways, it will appear as a beautiful arc of brilliant and generally white light, in which it is almost always easy to distinguish a kind of head or nucleus followed by a long train of light; the head of the meteor will, generally speaking, be visible for two to four seconds, and will disappear without noise, or sometimes it is said with a *hissing noise* (a fact which is a matter of doubt), being finally hidden from view by trees, or houses, or sinking below the horizon, whilst the train or tail usually remains visible several minutes. Such was the case with the meteor seen on Sunday night, 22nd September, 1851, about eleven o'clock, from the London and Blackwall Railway. The night was very clear and bright; the meteor *appeared* to be about half a mile above London. The nucleus soon disappeared, leaving the train as a bright line of light in the sky. For the space of four or five minutes, the latter afterwards took an undulating form as if disturbed by the slight wind which was blowing at the time, and gradually disappeared also. We give a drawing of this meteor (Fig. 1) from a sketch published at the time in the 'Illustrated London News' (28th September, 1851).

Fig. 1.

Meteor seen on Sunday night, the 22nd of September, 1851, about eleven o'clock, from the London and Blackwall Railway, between Stepney and Bow Stations. (From a drawing in the 'Illustrated London News,' Jan. 28, 1851.)

It sometimes happens that the light given out by meteors is so intense as *to dazzle the eyes of the spectator* to such a degree that he is unable to distinguish any form whatever in the heavens, at least for some time. Such occurred a few years ago to my friend Mr. F. Pigou, when a fire-ball passed over Putney Heath, producing so sudden and vivid a glare, that he was quite unable to distinguish the form of the meteor. No detonation was noticed on this occasion; so that we may conclude that the meteor was at a very considerable distance from Putney Heath.

A magnificent meteor was seen on Monday, the 10th August, 1863, at Putney by my youngest sister; it appeared to travel S.W. to N.E. across the sky: "*The sky seemed to open, and a red ball of fire passed along with a hissing noise, leaving behind it a tail of light; it remained apparently stationary for a moment, having at this time a kind of rotary or spiral motion.*" No explosion was noticed.

But the best manner of acquiring an exact notion of these curious phenomena is, doubtless, by comparing a few of the most authentic observations. I have collected, for this purpose, the following accounts of meteors (fire-balls, bolides) which were not observed to let fall any stony or metallic bodies upon the earth near to the observer.

Dr. Wallis communicated to the Royal Society, in 1677, an account of "an *unusual* meteor," seen September 20, 1676, about seven o'clock in the evening; though it *seemed very low,* it was seen in most parts of England at the same time. The doctor heard of it from several persons who saw it in Oxford, Northamptonshire, Gloucestershire, Worcestershire, Somersetshire, Hampshire, Kent, Essex, London, etc. "In the dusk of the evening," he says, "there *appeared a sudden light equal to that of noonday,* so that the smallest pin or straw might be seen lying on the ground. And above in the air was seen, at no great distance as was supposed, a long appearance as of fire, like a long arm with a great knob at the end of it, shooting along very swiftly, and at its disappearing seemed to *break into small sparks or parcels of fire* like as rockets, or such artificial fireworks in the air, usually do. It was so surprising and of so short continuance that it was scarcely seen by any who did not then happen to be abroad; its duration by report was less than half a minute."

In 1714, Dr. Edmund Halley sent to the Royal Society an account of two extraordinary meteors, one of which was seen in 1708, on 31st July, between nine and ten at night, over Sheerness, and must have been, according to Halley, forty or fifty miles high. It appeared "to move with amazing velocity, darting in a very few seconds of time for about 12° of a great circle from north to south, and it died away at the end of its course, *leaving for some time a pale whiteness in the place*, with some remains of it in the track where it had gone," but *no hissing sound as it passed*, or *explosion* were heard. Halley then describes "that famous meteor which was seen to pass over Italy on the 21st March, O.S. 1676, about an hour and three-quarters after sunset, which happened to be observed and well considered by the famous professor of mathematics, Geminian Montanari." This meteor was observed at numerous places, and was estimated to be about 38 miles high. It crossed over the Adriatic Sea and the whole of Italy, and wherever it was observed "it was heard to *make a hissing noise* as it passed, like that of artificial fireworks." Its velocity was estimated at 160 miles per minute; "which," adds Halley, "is about ten times as swift as the diurnal rotation of the earth under the equator, and not many times less than that with which the annual motion of the earth about the sun is performed." At Bologna the nucleus or head of the meteor *appeared* "larger than the moon in one diameter, and above half as large again in the other;" which, from its distance of about 50 miles from that town, makes its lesser *diameter about half a mile.** This meteor passed over Leghorn out to sea towards Corsica; at Leghorn it was heard to give "*a very loud report*, like a great cannon; *immediately after which another sort of sound was heard, like the rattling of a great cart running over stones*." It is almost impossible to have a more careful description of a bolide; it will be seen to agree perfectly with what has been since observed.

In 1718, Halley described another great meteor, seen all over England on the 19th March of that year. It was observed by Sir Hans Sloane, Vice-President of the Royal Society. "Walking in the streets of London at about a quarter after eight at night, he was surprised to see a sudden *great light far exceeding that of the moon*, which shone very bright. He turned to the westward where the light was, which he apprehended at first to be artificial fireworks or rockets. The first place he observed it in was about the Pleiades, northerly, *whence it moved after the manner of a falling star, but more slowly*, in a seeming direct line, descending a little beyond and below the stars in Orion's belt, then in S.W. The long stream appeared to be branched about the middle, and the meteor in its way turned pear-fashioned or tapering upwards [by 'the meteor' is meant here the head or nucleus]. At the lower end it came at last to be larger and spherical, though it was not so large as the full moon." Its colour was whitish, with a tint of blue, of a most vivid, dazzling lustre, which seemed in brightness nearly equal to that of the sun. "This *brightness obliged him to turn his eyes several times from*

* In a future chapter we shall see how much this estimate is exaggerated. (*Vide* Chapter XIV.)

*it*, as well when it was a stream as when it was pear-fashioned and a globe." There was *left behind it a track* of a faint reddish-yellow colour, which *continued more than a minute*, seemed to sparkle, and kept its place without falling. This track was interrupted, or had a chasm towards its upper end at about two-thirds of its length. *No noise was heard.* The place in the sky where the globe of light had been, continued for some time of the same reddish-yellow colour as the stream, and at first *some sparks seemed to issue from it*, such as come from red-hot iron beaten on an anvil. Halley calculates that this meteor ran about 300 miles per minute. For the few seconds that it lasted the darkness of night was changed into the light of noonday with a bright sun. *This meteor was heard to explode in Cornwall and Devon, though no noise was heard from it in London;* the "*report was like that of a very great cannon*, or rather of a broadside at a distance, *which was soon followed by a rattling noise*, as if many small arms had been promiscuously discharged." The noise shook the glass windows and doors of the houses.

The next observation I shall recall is that of a celebrated meteor seen by many persons in England on 11th December, 1741. This is a case of a meteor *occurring in bright daylight.* We have many similar cases, but none, perhaps, more remarkable than the following:—The first account of it is given in the publications of the Royal Society, by Lord Beauchamp. Being near the mount in Kensington Gardens at a quarter past [before?] one in the morning, *the sun shining brightly in a serene sky*, his lordship saw, towards the south, a ball of fire, which appeared to be about eight inches in diameter, and somewhat oval; it soon enlarged until it appeared about *a yard and a half* [!] in diameter. It seemed to descend from above, and at the *apparent* distance of about half a mile from the earth, took its course to the east, and seemed to drop over Westminster. In its course it assumed a tail which *apparently* was eighty yards in length; and before the meteor vanished it divided itself into two heads. "It left *a train of smoke* all the way as it went, and from the place where it appeared to drop there arose a *smoke which continued* ascending *for twenty minutes,* and at length formed a *cloud* which assumed *different colours.*"

This meteor, it seems, was heard to explode in Sussex; on that day, at Bucksteep, Mr. Christopher Mason observed, about a quarter before [past?] one in the afternoon, a very dark uncommon appearance [cloud] in the north, whilst the sun shone brightly at his back; when suddenly there was an explosion as violent as the report of a mortar-piece, attended with a rumbling echo, which ran eastward. Several people saw a ball of fire which moved nearly eastward, leaving a train of light smoke which continued for some time. The ball of fire was seen and the report heard very loudly at Sompting, beyond Shoreham.

Mr. Benjamin Cooke also forwarded some observations on this meteor from Newport, in the Isle of Wight: it was seen to pass by that place to the eastward at the *apparent* height of thirty feet from the ground of a hill on which the observer was placed, and at the *apparent* distance of a quarter of a mile from the place. Its colour was that of a burning coal; its figure, that of a cone, with an apparent length of eight feet and diameter of eighteen inches. From the point of this cone, or hinder part of the meteor, issued several bright streams sparkling with fiery drops. Its motion was "*without any noise*, wind, or motion of the earth attending it."

Captain William Gordon describes this same meteor: it appeared to him on Friday, the 11th of December, 1741; at about one P.M., whilst coming by water from the City to Whitehall, and when near to Hungerford Stairs, there appeared to Captain Gordon, "between Vauxhall and Lambeth, a body of fire: *it sprang upwards* in its ascent *almost perpendicular* to the horizon, to the height of about 35° in the space of a few seconds, and nearly in the form of a large paper kite, projecting a long tail towards the north-west, [therefore running east,] not unlike those of slips of paper set on fire." In this state it continued so long that he made the waterman lay by his oars, that he might observe whether it was the work of art or nature, as he was in some doubt.

It had, from its first appearance, expanded itself considerably, so that the extreme breadth was seemingly equal to the diameter of a full moon at the horizon. "In this form it continued ascending for the space of two *minutes* [?] gently shooting to the north-east, till it arose to about 45°, then *suddenly quitting its tail*, which vanished, colouring the neighbouring clouds with a yellow tint on their separation, it formed itself first into a ball of fire; then shooting quickly to the south-east in a stream of light, *disappeared, making a noise like a clap of thunder* at some distance, and *leaving behind it a smoky substance* in its track."

Another meteor was seen on Sunday night, the 26th of November, 1758, and described by Dr. John Pringle, F.R.S. It was seen almost simultaneously from Cambridge to Carlisle, Dumfries, Lanark, and in Ayrshire. Here its *tail was seen to break off* and to disperse in bright sparks of fire, while the head continued to move on in the same direction, north-west. Its *velocity* appears to have been *about double that of the earth* in her orbit round the sun, or about thirty miles per second.

Dr. Blagden has described a meteor, seen August 18th, 1783, which appeared as a luminous ball, leaving a train behind and yielding a prodigious light. It appeared in the N.N.W. and passed to the east, verged southward, and disappeared. It continued *visible about half a minute*. This meteor was seen at Paris, Brussels, Ostend, Calais, Cambridge, Suffolk, Essex, Lincolnshire, Yorkshire, Edinburgh, Aberdeen, and the Hebrides and Shetland Isles; also at sea; that is, through a course of 1000 miles at least. It was calculated to be about fifty-seven to sixty miles high. It was heard to explode in Lincolnshire and in Kent. From its apparent diameter, Dr. Blagden calculates that it was half a mile across, and two miles long (oval), whilst its train was ten or twelve times longer than the body. It moved at a rate of twenty to twenty-five miles per second. Its size must have been that of a considerable mountain,* and its motion much greater than that of the earth in her orbit.

In 1788, a friend of Alexander von Humboldt saw, *in the middle of the day*, at Popoyan, a fire-ball meteor, which was so brilliant that the room of the observer was entirely illuminated by it, in spite of the full light of the sun, shaded by no clouds whatever.

In the present work we shall have to relate many other meteoric observations, some of which are more curious than any of the preceding.

* *Vide* Chapter XIV.

# CHAPTER V.

## REMARKS UPON THE PRECEDING CHAPTER, AND FURTHER OBSERVATIONS.

We have seen hitherto only a part of the phenomena presented by meteors. The most remarkable portion of their history is that they invariably let fall upon the earth or in the sea a certain quantity of metallic or stony fragments. When a meteor passes over the head of an observer, and no noise or explosion is afterwards heard by him, the fall of stones or metallic masses from that meteor occurs at a very great distance, perhaps at some thousand miles; but when a meteor is heard (and seen) to explode, the fall of aerolites from it occurs within a comparatively small distance, generally from one to twenty miles of the observer. Before calling attention to certain meteors that have been seen to drop stones (aerolites) we must refer to a few more modern observations. In the preceding chapters I have carefully *italicized* any circumstance more particularly to be noted, with regard to meteors; any phrase thus printed in italics constitutes a well-observed and special character, peculiar to this particular class of phenomena. I find in my notes the following authentic observations, which it is perhaps worth while to relate here:—

On the 13th of September, 1824, *while the sky was calm*, a small fire-ball was seen at St. Petersburg; it appeared in a south-westerly direction, was of a pale blue colour, and descended towards the earth, at an angle of about 35°. The long and luminous tail which followed the globe of fire, had also a blue tint. No explosion was heard (Ann. de Chim. xxx. 2nd series, 1825).

On the 27th of November, 1824, about a quarter to six in the evening, M. Hallaschka observed at Prague a fire-ball which appeared about the size of the full moon, and spread on all sides a most vivid white light. Its borders shone with a blue light. It remained visible for four or five seconds. It moved from south-east to north-west. *When this meteor had disappeared, there appeared certain luminous radiations* which disappeared, in their turn, in the course of a few seconds. (*Idem.*)

On the 2nd of January, 1825, a luminous meteor (fire-ball) was seen, whilst the sky was calm and serene, on the route of Arezzo in Italy; it moved from west to east with much rapidity. It showed a nucleus and a tail very distinctly; the tail was much spread out, like a fan, sparks shot out from it and were lost in the air. It disappeared behind some poplar-trees. No noise or detonation was heard; *no odour was left* where it passed.

At half-past nine in the evening, on the 10th of September, 1825, at Liancourt (Oise), a fire-ball of an elliptic figure, and about the size of the full moon, was observed; it was followed by a luminous train, moved from north-west to south-east, appeared to descend at an angle of 35°, and seemed to fall into a little river that traverses the park of Liancourt. The sky was serene; the meteor had a white, silvery, and vivid light; it left no odour.

The 14th of November, 1825, at eight in the evening, a very brilliant fire-ball appeared at Leith, in Scotland. It moved from east to west, with great velocity, ran through an arc of 25° in the same direction, and *exploded at the zenith* like a rocket. *The luminous trace* this meteor left in the heavens *was visible for two minutes* after the fire-ball had disappeared.

On the 1st of December, 1825, at five in the evening, a fire-ball was seen at Berlin; it was the size of the full moon, its light was dull and reddish, *and it disappeared without leaving any trace, aud without having changed its place.*

These five observations, collected by François Arago, together with those already noted, will show what curious forms fire-balls sometimes assume, according to the direction in which they are viewed, that in which they move, their proximity to the observer, etc. It will be seen, however, that they all present certain phenomena in common; by which it is easy to distinguish them from any other kind of luminous meteor, such as globular lightning, aurora streams, Will-o'-the-wisp, or those curious emanations of light from the earth and the atmosphere, detailed by me in another work.* I will not multiply these examples, as I shall have to speak presently of meteors observed to fall to the earth, or to drop stones, etc., and shall close this chapter with the account of one or two fire-balls observed in recent years.

On the 13th of August, 1852, many persons at Sidmouth saw a brilliant fire-ball at twelve minutes past nine in the evening, at 15° west of the constellation Cassiopeia. It was about the size of the full moon, and of a very dis-

* 'Phosphorescence,' etc., London, 1862.

tinct yellow colour. It soon took the form of a fixed band in the sky, 1° wide and 7° 30′ in length. Sixty seconds later the band lost its shape, and transformed itself into a little cloud of white diffused light, which lasted for two minutes more, and then disappeared. It was about 30° above the horizon. ('Cosmos,' 11th of December, 1852.)

A similar meteor was seen by Professor Montigny, of Namur, on the 5th of October of the same year, at forty minutes past seven in the evening. (*Idem.*)

An extraordinay meteor appeared at New York on the 20th of July, 1860, at a quarter to ten at night. The atmosphere was sultry, and no movement in the air. A light cloud appeared in the west, from which a blue-tinted luminous globe shot out. It instantly lost its globular form, bursting, like an immense skyrocket, into four portions. The first two resembled brilliantly illuminated chandeliers, with innumerable jets of purple flame; the others were globular, and comparatively small. They maintained their relative distances as they flew across the sky from west to east, occupying in their flight something like a minute. About *a minute after their passage a detonation was heard,* as from a piece of ordnance. Although it did not *appear* above a quarter of a mile high, the elevation of this meteor must have been considerable, as it was seen almost instantaneously and with the same appearance on a radius from sixty to ninety miles around New York.

In the month of December, 1863, several very fine meteors were seen, and described in the 'Times' and other daily papers. Indeed, not a year, we might almost say scarcely a month passes without a brilliant meteor (fire-ball) such as those described in this and the preceding chapter, showing itself in some part of the country. And as to "shooting stars" (falling stars), which I will endeavour to prove are merely smaller meteors at a considerable distance,* we shall see that they occur at certain regular intervals, twice or three times a year in greater number than at any other periods, though they, also, are noticeable throughout the whole year.

It sometimes happens that a large and brilliant meteor is followed in the course of a few years by another quite as brilliant, which, occurring at nearly the same date, seems to take the same path in the heavens. In connection with this, and regarding the height, now well ascertained, at which meteors generally occur, I will quote the following observation published in the 'Times' of the 19th December, 1863, by Mr. Alexander S. Herschel upon a fire-ball seen in England on December 5th, 1863. At Collingwood, near Hastings, as at Inverness, in Ross-shire, this fire-ball illuminated *a cloudy sky, amid thick drizzling rain,* with the brightness and semblance of a flash of lightning. The same appearance was described at Ulverstone, in Lancashire, where the light appeared at the zenith. The numerous accounts which were published in the various newspapers failed to define the track of this meteor with precision; but it appears evident to Mr. Herschel that it closely pursued the path of another large meteor, observed on the 8th of December, 1861. The latter passed from 110 miles above the neighbourhood of Hull to 45 miles above the Irish Sea, between Lancaster and Douglas, in the Isle of Man. "The second visitation of the same district by a large meteor," says Mr. Herschel, "is probably an accidental circumstance; but the date from the 5th to the 8th of

* An opinion I have some time held, and which Professor Haidinger, of Berlin, seems to have also adopted latterly.

December may be looked upon as favourable to the appearance of fire-balls of large size, in every geographical position." The whole month of December appears in some years to be as rich in meteors and falling stars as the April, August, and November periods, to be referred to in the sequel.

A very brilliant meteor, seen on Sunday, December 17th, 1863, at Newcastle-on-Tyne, and at Gloucester, was observed to "sail slowly across the heavens in a south-west direction, lasting for three or four seconds; but did not explode; and on the 27th of December, 1853, another meteor was noticed, spanning the Channel from S.E. to N.W., and exploded.

We will now pass on to an extremely interesting portion of our subject.

# CHAPTER VI.

FIRE-BALL METEORS LET FALL UPON OUR GLOBE METALLIC OR STONY MASSES, GENERALLY KNOWN AS AEROLITES.—OBSERVATIONS UPON THE REMARKABLE FALL AT AGRAM.

ALL fire-balls or bolides let fall and scatter upon the earth, or in the sea, the whole of their mass, in the shape of metallic fragments, principally composed of *iron* (never exempt from certain *earthy compounds*), or in the shape of *stones*, or even *dust*, containing more or less *iron*, and generally capable of acting powerfully upon the magnetic needle.

Such a fall of stones or metallic masses upon our globe occurs shortly after the explosion of the meteor has been heard. We shall see presently, however, all the circumstances connected with these falls.

Showers of stones and metallic masses have been noted by very ancient writers; and to prove that the ancients were perfectly acquainted with the phenomenon of the apparition and explosion of fire-balls in the air, followed by a fall of stones or metallic masses of iron, I shall bring forward later a few striking accounts. In modern times no particular attention was paid to these ancient accounts, until the appearance of Luke Howard's celebrated paper in 1802, preceded by that of Chladni; both of which I have alluded to in a former chapter.

The first remarkable fall which appears to have attracted much attention in modern times, is that which took place at Hradschina, near Agram, in Croatia, on the 26th of May, 1751, about six o'clock in the evening. The sky was quite clear at the time, when a fire-ball, such as I have already described, was seen to shoot along the heavens with a hollow noise, and from west to east. It soon exploded with a very loud report, accompanied by a great smoke or cloud, from which two masses of iron, in the form of chains welded together, fell to the earth. A specimen of this remarkable aerolite, a fragment weighing twelve ounces twenty grains, is preserved in the British Museum, along with a great number of other aerolites.*

This aerolite of Agram is remarkable as having been long supposed to be the *only* well-observed case of the fall of a *metallic* mass, containing little or no stony matter. This is no longer true as regards modern falls. Numerous metallic masses have been found upon the earth, and no doubt prevails as to their meteoric origin; but most of the aerolites that have been observed to fall in modern times contain a considerable portion of earthy matter as well as metallic iron. In a future chapter, when treating of the composition of these stones, we

* I have said, in Chapter I., that aerolites have all the same peculiar composition (which we shall examine later), being composed of various silicates or earthy matter, and metallic iron, more or less alloyed with nickel, etc. Now, in some, the earthy matter predominates to such an extent that few or no metallic parts are visible, whilst others present the appearance of metallic iron itself. Such is the aerolite of Agram; and these iron masses have be en seldom *oberved to fall*, though many have been *found* upon the globe.

shall refer again to this. I find, however, in Chladni's celebrated catalogue, (Ann. de Chim., 1826,) compiled with so much labour, that there are several cases on record, more or less authentic, of iron masses having been seen to fall. The first was about 1009, when a mass of *iron* fell in the province of Djorjan (on the authority of Avicennes); in 1112, according to Valvasior, it is uncertain whether stones or *iron masses* fell near Aquileja. In 1164, *iron* fell at Misnia, according to Fabricius; and Siebrand Meyer asserts that *iron* masses fell in the district of Oldenburg about 1368 (date uncertain). Between 1540 and 1550 a mass of *iron* is said to have fallen in the forest of Naunhof; and both Mercati and Scaliger affirm that *iron* fell in Piedmont about the same date. Kronland asserts that a *metallic* mass fell in Bohemia, in 1618, and John Guir writes that on the 17th of April, 1621, a mass of *iron* fell near Lahore. The next case on record is that of Agram, in 1751, above mentioned, which was well observed. Since then, *iron* masses have been seen to fall in 1835 (July 30th), in Dickson County, Tennessee (North America); in 1847 (July 14th), at Braunau, in Bohemia, and on October 18th, 1854, at Taberg, near Gotha, in Saxony. These are mere details, showing that aerolites having a *purely metallic appearance* have undoubtedly been *seen to fall*, several distinct times, though in the greater number of aerolites observed in modern times, the amount of uncombined *metal* usually varies from one to twenty-five or thirty per cent. of the whole.

In the following rapid indication of some remarkable falls, I shall restrict myself to the latter half of the eighteenth century.

# CHAPTER VII.

ACCOUNTS OF THE MOST REMARKABLE AND WELL-OBSERVED FALLS OF AEROLITES THAT OCCURRED DURING THE LATTER HALF OF THE EIGHTEENTH CENTURY.*

Two years after the fall at Agram, in 1751, namely, on the 7th of September, 1753, at *one o'clock in the afternoon,* the weather being very hot and sultry, and *no appearance of clouds,* a tremendous noise was heard at Pont-de-Vesle, in France, and at Liponas; it was like the *discharge of two or three cannons,* and was heard for six or eight leagues in all directions, *accompanied with a hissing and a rattling sound.* The same evening, at Liponas and at Pin, Department de l'Ain, were found two uneven blackish masses, which had fallen on ploughed land, and sunk about half a foot below the surface. One of them weighed about twenty pounds; it is grey, with metallic particles disseminated through it; a specimen exists in the British Museum.

On the 13th of September, 1768, at about half-past four in the afternoon, *there appeared* near the Château de

* In some accounts left us of these falls, the dates have been misprinted. In some instances it has been difficult to decide which of two dates was the exact one.

Chevabrie, near Luce, four miles west of Chartres, "*a stormy cloud*," which, according to the Abbé Bachelay, produced a peal of *thunder, like the discharge of cannon, followed by a noise, which was mistaken by several people for the lowing of cattle.* No flame or light was observed, but the sound was heard over a space of about two and a half leagues. About three leagues from Luce, at Perigué, some reapers, hearing the same noises, looked up, and saw an opaque body describe a curve in the air, and fall on soft turf, near the *chaussée*, or high-road, from Mons, near which they were at work. They all ran up to it, and found a sort of stone half buried in the earth, but *so hot that they could not touch it.* "They ran back with fear; but, after awhile, returned, when they found the stone as they had left it, but quite cool;" it weighed seven and a half ounces. (There is a specimen of this fall in the British Museum.)

On the 20th of November, 1768, a similar stone fell, with a hissing noise, at Mauerkirchen, in Bavaria, it weighed thirty-eight pounds; a fragment of it, weighing ten ounces, is preserved in the British Museum.

An inhabitant of Saint-Sévère wrote to M. Darcet, the chemist, in Paris, on the 25th of July, 1790: "Our townspeople were very much alarmed yesterday. About a quarter past nine in the evening, a fire-ball suddenly appeared in the heavens; it had a long tail, and diffused a vivid light over the whole country. The meteor soon disappeared, and seemed to fall at a hundred paces from us. It was quickly followed by an explosion, louder than that of a cannon or of thunder. Everybody dreaded being buried under the ruins of his house, which seemed to give way from the concussion." The same phenomenon was seen, and the report heard, in the neighbouring towns of Mont de Marsan, Tartas, and Dax. The weather was fine and calm, and the moon shining brightly. Many stones were thrown to the earth by this meteor. But let us take M. Baudin's account of it. He was walking with M. Carris, of Barbotan, in the courtyard of the castle of Mormes, about half-past nine o'clock in the evening of the 24th of July, 1790, the air being perfectly calm and the sky cloudless. They found themselves suddenly enveloped in a pale clear light, much brighter than that of the moon, then nearly full. On looking up, they observed a fire-ball, which appeared as large as the moon itself, straight overhead, and dragging a tail five or six times longer than the apparent diameter of the head, and which tapered to a point. The end of the tail was blood-red, the rest of the meteor being pale white. It passed with great velocity from south to north, and in two seconds split into portions of considerable size, like the bursting of a bomb. These fragments became extinguished in the air, assuming, as they fell, that deep red colour before observed at the point of the tail of the meteor. *Two or three minutes afterwards* M. Baudin and his friend heard a tremendous explosion, like the simultaneous firing of several pieces of cannon. The concussion of the atmosphere shook the windows in the castle, and threw down kitchen utensils from the shelves. When the two gentlemen passed into the garden, *the noise still continued*, and appeared to be directly overhead. Some time after it had ceased, they heard a hollow sound rolling in echoes along the Pyrenees, and dying gradually away in about four minutes. Judging from the interval which occurred between the bursting of the meteor and the loud report, M. Baudin imagined that this fire-ball must have been at least eight miles above the earth, and that it fell about four miles from Mormes. This was soon confirmed by the account which reached them, of many stones which fell from the atmosphere at that time at Juillac and Barbotan, fragments of which were found lying in an almost circular space, nearly two miles in diameter. They weighed eighteen, twenty, and some as much as fifty pounds. Some are preserved at the Jardin des Plantes, of Paris; there is also a specimen in the British Museum. It has been stated that one of these stones, fifteen inches in diameter, broke through the roof of a cottage, and killed a herdsman and bullock.

The next fall which attracted attention was that which occurred at Sienna, in Tuscany, on the 16th of June, 1794, to which I have alluded in a former chapter; specimens were forwarded to the Royal Society, and an account of the fall published in Philosophical Transactions for the year following. The stones contained two per cent. of metallic iron. This fall is one of the most important on record, as having contributed so much to the history of aerolites; for it was the recollection of it that called serious attention to that which occurred the year following, in our own country. Nevertheless, the only account we have of this fall at Sienna, is that which is conveyed in a letter by the Earl of Bristol to Sir William Hamilton, and incidentally (!) inserted by the latter in his account of the eruption of Vesuvius (Phil. Trans., 1795, p. 103):—"I must here mention," says Sir W. Hamilton, "a very extraordinary circumstance that happened near Sienna, in Tuscany, about eighteen hours after the commencement of the late eruption of Vesuvius, on the 15th of June (1794), although that phenomenon may have no relation to the eruption." He then quotes the letter of the Earl of Bristol (written on the 12th of July, 1794). "In the midst of a most violent thunder-storm,* about a dozen stones, of various weights, fell at the feet of several men, women, and children. . . . They *are unlike any stones in Tuscany*. . . . They fell about eighteen hours after the enormous eruption of Vesuvius, at a distance of two hundred and fifty miles from that volcano. One of the largest stones weighed five pounds, another about one hundred and sixteen. . . . They are *black and vitreous on the outside,* their *inside being light grey*." It is evident that the worthy bishop, the Earl of Bristol, took these stones for volcanic products, and marvelled at their being transported to a distance of two hundred and fifty miles. Sir W. Hamiliton, on the contrary, doubts that they had any connection with the eruption. At the present day, it is well known that the stones which fell at Sienna are true aerolites. A specimen, weighing about three ounces and a half, is in the collection at the British Museum; their aspect, chemical composition, etc., leave no doubt as to their meteoric origin.†

On the 13th of December, 1795, about three o'clock in the afternoon, a very large meteoric stone fell in Yorkshire, close to Wold Cottage, Thwing, the property of Captain Topham. This gentleman inserted an account of the fall in the 'Gentleman's Magazine' for 1796; and the stone, weighing about fifty-six pounds, was submitted to chemical analysis, by Howard, in 1802. The specimen, as it was originally picked up, is now preserved in the British Museum. (Fig. 2.)

* Probably the noise of the explosion of the meteor.

† On some stones which fell during this eruption, near Naples, see Chap. III. of this work.

Another fall of aerolites occurred in Portugal, on the 19th of February, 1796; it is alluded to by Southey in his letters from Spain and Portugal; we have no specimen of this fall in England.

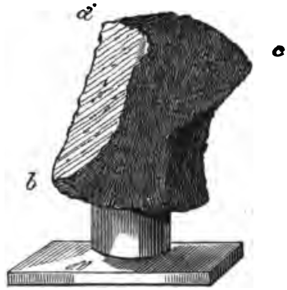



Fig. 2.

Meteoric stone, which fell at Wold Cottage, Yorkshire, (one-tenth nature,) from a drawing, by the Author, of the specimen in the British Museum.—*a b*, surface, cut and polished, to show the internal structure of the stone; *c*, dark-coloured crust, or rind.

A remarkable fall occurred at Salles, near Villefranche, Département du Rhône, France, on the 8th of March, 1798. On the 12th of March following, one of the stones picked up was forwarded to M. Sage, Professor of Chemistry in Paris,* and member of the National Institute, who described it as being of an ash-grey colour, granular, speckled with pyritous particles, and having a dingy black enamel above one-third of a line in thickness; the stone, moreover, acted powerfully upon the magnetic needle,—characters which usually appertain to aerolites. M. de Drée saw the meteor from which this stone fell, and gave an account of it in the 'Journal de

* The same who got enough gold out of the ash of the vines growing on the banks of the Seine to strike three gold napoleons. (See my article on "Gold, its Chemistry and Mineralogy," in 'Macmillan's Magazine,' 1863.)

Physique.' He states that the fire-ball had scarcely fixed the attention of the inhabitants of Salles and the adjacent villages, when its rapid approach, accompanied by a loud whizzing noise like that of an irregular hollow body traversing the air with great velocity, inspired the whole community with alarm. It did not appear to be very high in the atmosphere; it left behind it a long train of light, and emitted, with an almost unceasing crackling, small vivid flames like little stars." The stone forwarded to M. Sage fell at about fifty paces from three labourers, who were surprised at the astonishing rapidity of the meteor, and the hissing noise which appeared to proceed from the spot where the stone fell. We have a fragment weighing upwards of six ounces in the British Museum collection.

One of the most remarkable falls that ever occurred was that which was observed near Benares, in India, which is especially interesting in an historical point of view, as having furnished an important point of comparison with other subsequent falls. It was on the 19th of December, 1798, and about eight o'clock in the evening, that a very luminous meteor was seen in the form of a large ball of fire. It was accompanied by a loud noise like thunder, which was immediately followed by the sound of the fall of heavy bodies. Stones were seen to fall from it at Krahut, a village fourteen miles from Benares. On examining the ground, it was observed to have been freshly torn up in many places, and in the cavities thus produced stones were found of a peculiar appearance, many of which had buried themselves to the depth of half a foot. At the time this meteor appeared the sky was perfectly serene; not a vestige of cloud had been noticed since the 11th of the month, nor were any observed for many days after. The fire-ball was first observed in the western portion of the sky, and was visible only a short time. The light it emitted was so great that it cast strong shadows of the bars of a window on to a dark carpet, and for the moment, the night appeared as luminous as in the clearest moonlight. Many of the stones which fell were collected, some of them weighed as much as two pounds each. A small specimen, about six ounces, exists in the British Museum collection. Mr. Howard examined these stones in 1802. Externally they are covered, like other aerolites, with a hard black coating or enamel, which in some parts has the appearance of a black varnish. Internally they are of a whitish-grey colour, interspersed with bright shining particles like pyrites, and a number of spherical bodies of a slate colour, imbedded in the whitish-grey gritty substance of the interior. The white portion crumbles easier than the rest, and its powder is in great part attracted by the magnet; the outside crust or enamel was found to be very magnetic.

## CHAPTER VIII.

### ON SOME REMARKABLE FALLS OF AEROLITES OBSERVED DURING THE FIRST HALF OF THE NINETEENTH CENTURY.

The aerolites seen to fall in the course of the present century have been so numerous, that I am obliged to restrict myself here to a few of the more remarkable, which deserve especial attention on more than one account.

The most important in an historical point of view, as being the first phenomenon of this kind which attracted the attention of the scientific men in France, and established in that country as clear a conception of the nature of fire-balls and aerolites as that which had been gained in England, was the remarkable fall which happened near L'Aigle, in Normandy, on Friday, the 26th of April, 1803. It occurred a little after one o'clock in the afternoon, the sky being clear, with the exception of a few light fleecy clouds, when a fire-ball was simultaneously observed at Caen, Falaise, Alençon, Verneuil, Pont-Audemer, and other places in Normandy. It moved rapidly from south-east to north-west, and in the district of L'Aigle, at this moment, loud explosions were heard, which lasted for five or six minutes; they resembled "the sound of cannon and musketry," and were followed by a long-continued noise, "like that of many drums." The meteor from which the noise proceeded appeared not so much like a ball of fire, but rather like a *small rectangular cloud*, which during the phenomenon seemed not to move, but the vapour of which it consisted was shot out, in all directions, at each successive explosion. It seemed to be about half a league north-west of L'Aigle, and must have been at a considerable elevation, as it appeared to the inhabitants of two villages, more than a league distant from each other, to be immediately over their heads at the same moment. Throughout the whole district over which the cloud hung there was heard a hissing noise like that of a stone from a sling, and a vast number of stones fell to the ground. The space on which they fell formed an ellipse of two and a half leagues long by one league broad,—the larger diameter being from north-east to south-west; the direction in which the meteor moved. The largest stones were found at the south-east of the ellipse, and the smallest at the opposite extremity. About 2000 stones were collected, varying in weight from two drachms to seventeen and a half pounds. Such is one account of this most remarkable fall. Here is another, extracted from a letter by M. Marais, a citizen of L'Aigle:—"An astonishing miracle has just occurred in our district. . . . On Friday, the 26th of April (1803), between one and two o'clock in the afternoon, we were roused by a murmuring noise like thunder; on going out we were surprised to see the sky pretty clear. . . . We took it for the noise of a carriage, or the firing of guns in the neighbourhood. We were then in the meadow to examine whence the noise proceeded, when we observed all the inhabitants of Pont-de-Pierre at their windows and in their gardens, inquiring about *a cloud* which passed in a direction from south to north, and from which the noise issued, although *the cloud presented nothing extraordinary in its appearance.* But great was our astonishment when we learnt that many and large stones had fallen from it (some of them weighing ten, eleven, and even seventeen pounds) in the open space between the house of the Buat family, half a league N.N.E. of L'Aigle, and Glos. . . . The following is the account given by all who witnessed it:—They heard a noise like that of a cannon, then a double report still louder than the first, followed by a rumbling noise, which lasted about ten minutes, the same which we also heard, accompanied by *hissings* caused by these stones. . . . Nothing more was heard." The country people appear to have been much alarmed; it is also noticed in the letter, that *before the explosions occurred, the domestic fowls appeared alarmed, and the cows bellowed in an unusual manner.*

I have stated in Chapter II. of this work, that the *savant* Biot was directed by the Academy of Sciences to proceed to L'Aigle and collect details regarding this fall. M. Biot's letter to the Minister of the Interior was published in the 'Journal des Débats.' He left Paris on the 5th of June, and went first to Alençon (fifteen leagues W.S.W. of L'Aigle) where he learnt that a *globe of fire* had been observed moving towards the north, and that its appearance was followed by a violent explosion. He afterwards proceeded to L'Aigle, and on the way assured himself that almost all the inhabitants of twenty hamlets, spreading over two square leagues, were eyewitnesses of "the dreadful shower of stones" which were darted from the meteor. The number that fell cannot have been less than *two to three thousaud.* It has been stated that some of these stones were very friable for some days after they had fallen, and that they had a strong sulphurous smell, which partially disappeared as the stone became harder, but was retained for a long time, and manifested itself long afterwards when any of the stones were broken. The great chemist Thenard analysed some of these stones; he found in them *silica, magnesia, iron, nickel,* and *sulphur.* Laugier afterwards found *chrome* in them. We shall refer again to their composition in another chapter. A specimen, weighing two pounds two ounces, may be seen in the British Museum.

No doubt both the *fire-ball* and the *cloud produced* by it were distinctly seen as remarked above. ' Often when aerolites fall in the daytime nothing but a *white* or *black cloud* is observed from which the explosions and showers of stones seem to emanate.

At Possil, near Glasgow, on the 5th of April, 1804, a meteoric stone fell with a loud hissing noise, preceded by explosions, etc.; there is a fragment in the British Museum. I have no account of this fall.

On the 15th of March, 1806, an aerolite fell at Alais, in the Département du Gard, France, to which we shall have to return later, on account of its peculiar composition. It is remarkable as containing a certain amount of *carbon*—a substance since discovered in some other aerolites; it consists of crumbling laminæ, as may be seen by inspecting the specimen of this fall, in the collection at the British Museum; it has a speeific gravity of only 1·94.

On the 14th of December, 1807, several aerolites fell at Weston, in Connecticut, North America; the stones penetrated some depth into the ground. These stones were projected from a very brilliant fire-ball meteor, the real diameter of which was estimated at about two hundred yards. It was perhaps one of the largest meteors ever seen, if we except one seen by Le Roi on the 16th of July, 1771, which was calculated to be about three hundred and seventy yards wide, and that observed by Sir Charles Blagden on the 18th of August, 1783, whose diameter was estimated to be half a mile,—an exaggerated diameter, however, as we shall see in a future chapter.*

On the 5th of August, 1812, an aerolite fell at Chantonnay, in La Vendée, France, of which there is a sample weighing one pound four ounces in a collection at the British Museum. This stone is remarkable as being cited by Humboldt as the only aerolite hitherto met with that has no black rind or crust; it is porous, shows vesicular cavities, and, upon analysis, appears to be composed of the minerals hornblende and labradorite.†

On the 6th of February, 1818, a brilliant meteor was seen at two o'clock at noon in the neighbourhood of Cambridge; it was seen also at Swaffham, in Norfolk, and near Banbury. It appeared large and highly luminous in spite of the bright sunshine, and was seen descending vertically from the zenith to the horizon in the northern hemisphere. It seemed to split into two portions before becoming extinct. No noise was heard and no stones observed to fall from it. But this meteor is in-

* In Chapter XIV.

† For the circumstances attending the fall of the curious aerolite of Chassigny, which fell in the year 1815, see Chapter XI. of this work.

teresting on account of the note published lately upon it by Dr. Joule, to which I shall refer in another chapter.

I must here enumerate, more or less rapidly, some of the most remarkable falls of aerolites that have occurred between the years 1820 and 1850.

Some meteoric stones, known as the Juvenas aerolites, fell on the 15th of June, 1821, at Juvenas, near Libonnez (Ardèche). These stones penetrated into the ground to a depth of several feet; they resemble the rock called dolerite, having pores and cavities, and containing distinct crystals of augite and labradorite. They have been chemically examined by several eminent philosophers, amongst others by Professor Rammelsberg; their composition, to which I shall refer in the proper place, is very remarkable by the absence of nickel and the presence of titanic acid. Besides a specimen, which weighs upwards of a pound, exhibited in the British Museum, we have a striking sample in the Mineralogical Museum at the Jardin des Plantes, in Paris, to which is appended the following interesting inscription:—

"Aerolite which fell at Juvenas, in the canton of Antraigues, in the arrondissement of Privas (Ardèche), on the 15th of June, 1821, about three o'clock in the afternoon, after a very violent meteoric explosion, which was heard at a considerable distance, and was followed by the fall of a great number of other stones much smaller, but of the same nature. This aerolite was not dug up until the 23rd of the same month; it had sunk to about eighteen decimetres into the soil, and weighed ninety-two kilogrammes (upwards of 184 pounds English) before it was broken by the workmen. It still weighs forty-two kilogrammes, and was bought in 1825 by the Museum."

The aerolite in question is covered with the usual black crustor rind, about one millimetre (four-hundredths of an inch) in thickness. It is curious to note that exactly a year after the fall of the Juvenas aerolite there occurred another similar phenomenon at Angers.

On the 3rd of June, 1822, some stones fell at Angers (some authors write 9th of June, others 9th of July; for the Angers meteorites, the 3rd is the date given in Chladni's catalogue, Ann. de Chim. 1826); they were supposed to fall from a *small* and *beautiful fire-ball* seen at Poitiers, where it appeared not larger than the lights of the fireworks called Roman candles. This minute meteor left behind it a straight streak, very narrow above, and very broad below, *which lasted for ten or twelve minutes* with great brilliancy. Seventeen miles north of Poitiers an aerolite fell with a great detonation, and is supposed to have proceeded from the meteor in question, but the phenomenon has not been sufficiently described.

A letter from Professor Orioli, of Bologna, to François Arago, describes an interesting fall of aerolites that occurred on the 15th of January, 1824, between nine and ten o'clock in the evening, in the parish of Renalzo, twenty-one miles from the town of Cento, province of Ferrara, in Italy. The fall was preceded by the apparition of a vivid light, and three loud explosions like those of cannon, followed by a noise similar to the discharge of musketry, and finally by a metallic sound like the rattling together of several pieces of metal. The stones, whilst falling, produced in the atmosphere a strong hissing noise. In spite of the obscurity of the night, it was possible to fix the direction in which they fell, and the next day several were picked up. A small fragment of one of them exists in the collection at the British Museum; another stone, in the possession of the Abbé Ranzani, weighs about a pound and a half. A third specimen, preserved in the Observatory of Bologna, weighs twelve pounds.

On the 14th of October, 1824, about eight o'clock in the morning, according to 'Schumacher's Journal,' an aerolite weighing several pounds fell near Zebrak, in Bohemia. It was found broken into two pieces, which were carried to the National Museum of Prague. A moment or so before, loud detonations were heard and several hissing noises in the air, so that it is highly probable, as Arago thinks, that many stones must have fallen.

Captain Harrison witnessed the fall of an aerolite *in the middle of the day*, on the 10th of February, 1825, between twelve and one o'clock. It occurred at Nanjemoy, in Maryland (North America). The sky was rather vapoury, the wind south-west, the fall of the aerolite was preceded by a loud explosion, followed by a keen hissing noise in the air. The stone was found only half an hour afterwards, at twenty-three inches under ground, *it was still warm,* and had *a strong sulphurous smell;* it weighed sixteen pounds seven ounces. Its exterior portion was covered with a vitrified brown crust or rind, exceedingly hard, whilst the interior was of a pale slate-colour and earthy-looking. Here and there in the substance were found dispersed hard globules of another colour aud of different sizes, and small quantities of a yellowish-brown pyritous substance. (See specimen in British Museum weighing about ten ounces.)

On the 5th of July, of the same year (1825), *an abundant shower of stones* fell at Torrecilles del Campo, in Spain, at *two o'clock in the afternoon.* They weighed from one ounce to one pound. Both men and animals in the fields are said to have suffered severely from this fall, which was described in the 'Gazette de Madrid' for the 18th of July, 1825. This short account is taken from the 'Annales de Chimie,' 1826.*

By consulting the list of aerolites preserved in the fine collection at the British Museum, it will be seen that a great number of falls have occurred in different parts of the earth's surface; of these, on account of their great number, I can only allude to the more remarkable, or to those which have an historical interest attached to them from having been the subject of minute investigation either in a meteorological or chemical point of view. It will be also observed by referring to this list, that it is not an uncommon occurrence that *two or more falls* of aerolites have occurred in *the same year*, on various portions of our globe.

*Three* separate falls are indicated in this catalogue as having occurred in the year 1827, and to these we must add a *fourth*, not indicated in the list. The first occurred on the 16th of February, 1827, at Mhow, Ghazeepore, India; the second on the 9th of May, 1827, at Drake Creek, Nashville, Tennessee, North America; the third on the 5th of October, 1827, at Bialystock, Knasta, in Poland; and the fourth on the 22nd of May of the same year, at Sommer county, North America; the latter gave rise to an elaborate paper concerning its composition by Baumhauer, to which I shall have to refer in another section of this work.

An aerolite which fell at Vouillé, Vienne, in France, has just been added to the collection at the Mineralogical

* We have accounts of several disasters that have been occasioned by the fall of aerolites.

Museum, in the Jardin des Plantes, of Paris.* This aerolite, which until now has been preserved in the Museum in Poitiers, fell under the following circumstances :—

During the night of the 13–14th of May, 1831, a luminous globe (fire-ball) was suddenly observed by the inhabitants of the town of Poitiers in the eastern portion of the heavens, its direction being from south to north. Its brightness resembled that of a great fire. Three violent detonations were soon heard; the noise resembled the loudest cannon, and was noticed as far as Rocheford, which is eighteen leagues from Vouillé.

The last detonation was followed by a deadened and distant sound, compared to that of a heavy cart rolling over uneven pavement. The latter noise lasted for a considerable time. It was unlike thunder by being quite uniform during the whole time of its duration. The next day, the 14th of May, a farmer residing in the village of Vouillé, four leagues south-west of Poitiers, on going into his vineyard, found an aerolite which had penetrated into the ground, had ploughed up the earth, and was found lying by the side of the hole it had made by its fall. It weighs about thirty-one pounds as it now exists, and it is estimated that at least a quarter of its bulk has been from time to time broken off for specimens, etc. It is covered with the ordinary black rind, and resembles very closely the aerolite of Château-Renard, of which I shall speak presently.

I must refer to the list above named for indications

* This collection, now under the direct superintendence of my friend Professor Daubrée, Member of the Institute, is rapidly increasing in importance, and promises to become very soon the finest collection in Europe.

of several falls about the period of which I am writing, and of which specimens are carefully preserved. I will only note that the aerolite which fell at Blansko, near Brünn, in Moravia, on the 25th of November, 1833, is remarkable as being composed entirely of hornblende and labradorite.

On the 13th of November, 1835,—a most remarkable *period* for shooting stars, as we shall see in the proper place,—some aerolites fell near Belmont, Département de l'Ain, France. According to Millet d'Aubenton, a fire-ball was seen, which exploded, and the stones which fell *set fire to some straw roofs in the parish of Belmont* (arrondissement de Belley). The circumstance is alluded to in Humboldt's 'Cosmos,' vol. iv. p. 585.

A very remarkable and well-observed fall of an aerolite on the 31st of January, 1836, has been recently brought forward by Professor Daubrée. It occurred at Mascombes, near Corrèze, in France, at *one o'clock in the afternoon;* the stone fell *within twenty yards of two gentlemen,* MM. Terrion and Soularue, who were out shooting. The fall was preceded by two detonations compared to distant thunder, followed by a hissing noise which appeared to come from the north. The weather was dark and rainy; no evolution of light was remarked. As soon as the two gentlemen had recovered from their alarm, they proceeded to dig up the stone which had buried itself in the damp ground to a depth of sixty-five centimetres (upwards of two feet English), it was not hot to the touch when extracted. It was about the size of a man's fist, and weighed rather more than two pounds. The interior of the stone is grey, like that of certain trachytes, granular, showing disseminated metallic grains, some iron-grey, others brassy-yellow, the iron it contains is alloyed with nickel, and the stone also contains magnetic pyrites,—in fact, it has the composition of ordinary aerolites.

On the 13th of October, 1838, an aerolite fell near Tulbagh, not far from the Cape of Good Hope; the fall was preceded by some very violent explosions in the air. It seems as if one stone had fallen, and in doing so burst into a considerable number of fragments, which fell scattered over a space of about 100 square feet. The total bulk of these united fragments was *estimated at five cubic feet.* The composition of the stone is remarkable by the presence of *carbon.* We shall refer to it again.

On the 12th of June, 1840, a stone fell at Staartje, near Uden, in North Brabant. The fall happened *in the morning,* between ten and eleven o'clock, the weather being calm and serene. Some loud detonations were heard at the same time, *preceded* by a continually increasing sound. In the pathway on which the stone fell it made a hole and threw up the earth round about it. This aerolite was *so hot* when first obtained that no one could touch it. It was about the size of a man's fist; was covered with a thin black rind, and presented a greyish-white interior, etc. (Baumhauer.)

A great number of meteoric stones fell in the year 1841 :—One which fell on the 12th of March, 1841, at half-past four in the evening, at Grüneberg, Heinrichsau, Silesia, weighed thirty-six ounces and a half. Like the aerolites of Stannern (1808) and Juvenas (1821), it appears to be composed of several distinct crystallized mineral substances.

On the 25th of February, 1841, a fire-ball was seen to *fall upon the roof of a house* at Chanteloup, in France.

The *house took fire immediately*, and burnt two other houses; but it is not stated whether the aerolite was found. (Poggendorf, 'Annalen,' liii. 221.)

But the most celebrated fall that occurred in 1841 was that at Château-Renard, Loiret (France), on the 12th of June, between *one and two o'clock at noon.* The stone burst into several pieces, which, taken together, weighed upwards of sixty pounds; a specimen, weighing seven pounds two ounces, exists in the British Museum collection. The chemical composition of this stone has been established with great care.

The following is a curious case of the recovery of an aerolite which fell in the year 1842:—On the 5th of December, 1842, about half-past five o'clock in the morning, a vivid light was seen south-west of Épinal, in France. Immediately afterwards a hollow distant sound was heard, which lasted for some seconds, and was compared to repeated discharges of distant artillery. From the heights of Saint-Antoine an immense globe of fire (fire-ball), extremely brilliant, was observed; it soon divided itself into three principal portions. One of these appeared to fall between the houses at Saut-le-Cerf, and seemed to roll along a field situated to the right of the road leading to Dogneville. Another portion split up into several parts and fell like a rain of fire over the town of Épinal, more particularly over the "Place de l'Atre." The third portion, which was the densest, shot like a streak of fire on to the hill of Eau-fromont, and struck the earth about halfway up this hill, on the side which faces the Moselle. Some persons who happened to be on the "Place de l'Atre," at Épinal, approached the little fragments, which appeared in a state of incandescence, and when they were cool found nothing but a little grey cinder, which does not seem to have been collected. At Saut-le-Cerf, in spite of the most persevering search, nothing could be found; nor were any meteoric stones collected on the Eaufromont. However, on the 7th of July, 1851, M. Guéry picked up what he considers an aerolite, a little way from the hill of Eaufromont. It was a ferruginous mass, weighing about 843 grammes, acting strongly upon the magnetic needle, some portion of it being smooth, the rest cavernous, and the whole having a specific gravity of 5·23. But the stone has not yet been submitted to chemical analysis, so that it is impossible to decide upon its nature. This interesting account of a fire-ball dividing itself into three distinct portions is taken from the journal 'Cosmos,' vol. i. pp. 438, 439.

Two very remarkable and well-observed meteoric phenomena occurred in the year 1843:—

On the 2nd of June, 1843, in the evening, a very violent explosion in the air was heard at Utrecht, and in the villages of the neighbourhood; it was compared to three or four discharges of cannon. These detonations were followed by a hissing or whistling noise similar to that of the wind or to the sounds emitted by an Æolian harp; at the same time a peasant saw a heavy body fall from the air into a field near Blaauw-Kapel, in the neighbourhood of Utrecht, which, on coming in contact with the ground, threw up a certain quantity of earth. Recovering from his astonishment, in about a quarter of an hour the peasant approached the place, and discovered a hole in the shape of a funnel, at the bottom of which was found a black stone, already cold. This stone had penetrated into the earth vertically, to a depth of more than a yard, and had stopped on arriving at a layer of damp sand; the loose earth displaced by the shock was heaped around the hole.

Three days afterwards, at two-thirds of a league from this place, near the village of Louvenhoutje, another black stone was found in a ditch (*fossé*), the fall of which had been also observed on the evening of the 2nd of June; it caused the water of the *fossé* to be splashed upwards to a considerable height, so that these stones must have reached the ground with a great velocity. The explosions were heard also at Rotterdam and at Leyden, both of which towns lie in the direction which the meteor appears to have taken.

The first of the stones weighed about fourteen pounds; the second weighed five pounds and a half; they are both covered with a hard blackish-brown rind, in which are seen certain parts indented, as if by pressure of a finger. Their interior is almost white, and shows here and there disseminated grains yellow and black, and a few metallic particles, some of which are reddish-purple. Dr. Baumhauer has analysed these stones with great care. (See Chapter XI.)

Near the village of Kleinwenden, in the district of Nordhausen (Prussia), long celebrated for its manufacture of strong sulphuric acid, there fell, on the 16th of September, 1843, a meteoric stone, weighing six pounds. This stone fell in the daytime, with a violent detonation, the sky being calm and cloudless. It has become one of the most remarkable specimens of aerolites, since the publication of Professor Rammelsberg's excellent researches on its composition. When picked up, the stone was still quite hot.

According to Alexander von Humboldt, a conflagration was caused by a fire-ball meteor on the 22nd of March, 1846, about three o'clock in the afternoon, in the *commune* of St. Paul, near Bagnère de Luchon. It is not stated whether any stones were found.

I terminate this chapter by alluding to a very remarkable meteorite, which was seen to fall at Braunau, in Bohemia, on the 14th of July, 1847, of which we have, in the British Museum collection, a specimen weighing as much as one pound four ounces. This most remarkable aerolite, which contains nearly *ninety-eight per cent. of nickeliferous iron*, (similar, therefore, to the Agram meteorite, etc.), and which has been most carefully investigated by Haidinger, Duflos, Fischer, and others, possesses a *most perfect cubic cleavage*, that is, splits up into cubes, with as much ease as the well-known lead ore, galena. It appears that several fragments fell to the earth, with the usual phenomena that accompany meteorites; and the metallic masses were so hot, that *for six hours (?) after the fall they could not be touched without causing a burn.* This seems to prove that the earthy aerolites, though they frequently have been observed to remain hot for some time, cool more rapidly than those of nearly pure metallic nature.

M. Giraud analysed an aerolite containing twenty-two per cent. of iron, which fell in a field to the south of Neglour, a village of Dhawar (India), on the 15th of February, 1848. This meteoric stone weighed about four pounds. (Ann. de Millon, 1850, p. 231.)

# CHAPTER IX.

ACCOUNT OF THE PRINCIPAL FALLS OF AEROLITES THAT HAVE BEEN WELL OBSERVED, FROM THE YEAR 1850 TO THE PRESENT TIME.

As the nature of aerolites and fire-ball meteors has become better known—a natural consequence of the constant progress of scientific research,—scarcely a shooting-star, or bolide, which shows itself to any civilized portion of our globe, escapes the most minute observation. It has been calculated that, on an average, seven hundred meteorites fall annually upon our earth. Many are doubtless lost in the ocean, which covers about seven-eighths of the globe's surface; but a great number are carefully collected and preserved in the different museums. In the short space of fourteen years, from 1850 to the present year, 1864, a considerable number of meteoric phenomena have been accurately observed, and many very interesting observations recorded. As before, I must restrict myself, here, to the most remarkable of these observations, reserving details connected with the chemical composition, etc., of the aerolites observed, for other sections of this work.

An aerolite of considerable size, weighing two pounds eight ounces, fell on November 30th, 1850, at Shalka, near Bancoorah, in Bengal. In 1851 two remarkable falls occurred, one on the 16th of April, at Gütersloh, in Westphalia (Prussia); the other on the 5th of November, at Nulles, in Catalonia (Spain),—a *natural* firework for the Spaniards!

In 1852 a considerable number of falls occurred. I myself know of no less than five that happened during that year, in different parts of the globe, namely, 23rd of January, 1852, a large stone at Yatoor, near Nellore, Madras; a specimen, weighing twenty-four pounds twelve ounces, may be seen in the British Museum. 4th of September, at Mezö-Madaras, Transylvania. 13th of October, at Burkut, Marmoros, Hungary. 2nd December, at Bustee, near Goruckpur, India. 17th December, near Dover, England.

The following is the account of the aerolite which fell on the beach near Dover, on the 17th of December, 1852, about five o'clock in the morning, as it was observed by Lieutenant Higginson, R.N. I give it in his own words:—"At three minutes past five A.M., the meteor having spanned the Channel from S.E. to N.W., upon approaching the land, evidently throwing off portions of its substance as it passed through the atmosphere with a terrific rushing noise, the nucleus suddenly exploded with a report similar to a heavy clap of thunder. The great body of the meteorolite seemed to fall in the water, about half a mile from land,—as indicated by a vast volume of spray, which rose foaming in the distance. From the extraordinary rattling report, I felt certain some portion of its substance had reached the shore. I therefore proceeded along the coast, in the direction pointed out by its fall, and, after some search, found several meteoric stones, or masses, of various sizes, scattered about, still hot."

This account must be accepted with some caution. I am indebted to W. T. Ryley, Esq., of Lee (Kent), for a copy of a pamphlet published by Lieutenant Higginson, and containing an account of the phenomenon in question. It appears, from a perusal of this pamphlet, that the author, no doubt, saw a very magnificent meteor, such as those already described; and that the weather, at the time, was stormy, with rain and south-west wind. But the stones he picked up, and subsequently forwarded to the Royal Society and elsewhere, turned out to be the common iron-pyrites, found along the southern coast of England, and which the peasants, not without some reason, have long termed "thunderbolts."* I have little doubt, on reading his rather vague acccunt of the phenomenon, that real meteoric stones must have fallen on or near the coast, and that he may possibly have picked up some of them along with the iron-pyrites, since he says the stones were hot.

On the 10th of February, 1853, some meteoric stones fell at Girgenti, in Sicily. On the 6th of March of the same year, some larger ones fell at Seegowlee, in Bengal. On May 13th, 1855, a fire-ball meteor, which shot over northern Germany, let fall some aerolites at Gnarrenburg, in Hanover, and on the island of Oesel, in the Baltic. On the 7th of July, 1855, a small aerolite fell at Saint-Denis-Westrem, near Ghent, Belgium; and on August 5th of the same year, some stones fell at Petersburg, Lincoln county, Tennessee (North America). On the 12th of November, 1856, a meteorite fell at Tren-

* See Chap. XV. of this volume.

zano, near Brescia, in Lombardy. Of these falls I have no details to give here.

The year 1857 is one of the most remarkable on record, as regards the number of meteoric phenomena and falls of aerolites. We have first to notice the immense aerolite which fell at Parnallee, in Madras (India), on the 28th of February, 1857. This stone fell with a thundering crash, in the middle of the day, about twelve o'clock; it split into several fragments, all remarkable by their size and weight. One of them, weighing thirty-seven pounds, was picked up by Mr. H. S. Taylor, and forwarded to Vienna; another, weighing no less than one hundred and thirty-four pounds, is now in the British Museum,—it is the largest aerolite, of the kind, in that collection. This stone has a peculiar tufaceous structure, as if formed by an agglomeration of fragments, more or less voluminous, some of which are white, and others of a dark colour.

The month following, on March 24th, 1857, a meteorite fell at Stavropol, on the north side of the Caucasus (Russia), and on the 1st of April, 1857, a similar fall occurred at Heredia, San José, Costa Rica. Only a fortnight later, on the 15th of April, 1857, a more celebrated aerolite fell at Kaba, in Hungary, of which I must add a few details:—

About ten o'clock at night, an inhabitant of Kaba, sleeping in the open air, was awakened by a noise different from that of thunder, as he described it, and perceived in the serene sky a luminous globe of dazzling brightness, following a parabolic course for the space of four seconds. This phenomenon was observed by several inhabitants of the same place. As one of them, Gabriel Szilagyi, was riding out the next morning, his horse shied at some earth recently turned up in the road; on dismounting, he found a black stone deeply bedded in the soil at this spot, the ground near it being depressed and creviced. When dug out, the meteorite weighed about seven pounds. Szilagyi broke off some fragments, and the remainder, weighing five pounds and a quarter, was deposited in the museum of the college at Debreczin. Kaba is south-west of Debreczin, in central Hungary. This meteoric stone was in shape and size like a small loaf of bread. It is covered with the usual thin black rind, having, like most aerolites, a few furrows and tubercles. The interior mass of the stone is greyish-black, with globular concretions, and acts energetically upon the magnetic needle. It resembles in structure the aerolites which fell at Renalzo in 1824. But the most remarkable part of the history of this aerolite is that it was found, on being analysed by Dr. Wöhler, Professor of Chemistry at Göttingen, to contain some carbon and a small quantity of an organic substance similar in nature to *paraffine*, to which we shall return when treating of the composition of these remarkable stones. We have not yet done with the year 1857.

An exceedingly remarkable shower of aerolites occurred on the 1st of October, 1857, in the commune Des Ormes, Yonne (France). The following is the account given of this fall by Baron Séguier to the Académie des Sciences of Paris:—

On the 1st of October, 1857, about a quarter before five o'clock in the afternoon, Baron Séguier was talking to some workmen in the avenue of his country-house at Hautefeuille, near Charny (Yonne), when suddenly five or six precipitous and very violent explosions were heard in the air. It was impossible to mistake them for thunder. "The ground appeared to tremble, and the trees were agitated by a movement of oscillation." These movements were doubtless executed by the Baron himself in his alarm, and related to external objects. The detonations were soon followed by a rather violent noise, which Baron Séguier compares to that which would be produced by coarse gravel falling from some height into the hold of a barge. This noise and the explosions caused a very vivid emotion among the workmen. Going into the house, it was found that the window frames had been very much shaken and loosened in several places. No one could account for the extraordinary phenomenon; but it was soon learnt that at that very moment a shower of aerolites had fallen with a hissing noise and violent explosions, etc., in the parish of Des Ormes, canton of Ailland-sur-Tholon (Yonne), at a few leagues from the Baron's house at Hautefeuille. A mason who was at work on a scaffolding in the district, had remarked the same explosion which we have just described, and, moreover, heard a number of projectiles fall to the ground with a loud hissing noise,—similar, according to his idea, to what would be heard if a cart-full of stones had been thrown violently to the earth. One of these *projectiles*, as he called them, had shot very near to his head, and had struck the ground at a short distance from his ladder. It passed through a tree a few yards off, bounding from branch to branch. He descended to pick it up, and found that the stone had sunk into the ground about half a foot. M. Séguier got possession of this stone, which is an ordinary aerolite, very small, covered with a thin black rind, and of a greyish granular interior; it is very similar to the stones which fell at L'Aigle (1803). The fire-ball meteor which accompanied this fall of stones at Des Ormes, was described by a gentleman residing at Château-Renard as a globe of fire about three yards wide, which moved with great velocity in the direction of the place where the stones fell. I saw a small specimen of this aerolite in the collection at the British Museum, and another in the collection at the Jardin des Plantes, in Paris.

On the 10th of October, 1857, an aerolite fell at Ohaba, a village east of Karlsberg, in Transylvania. It was seen to fall about midnight by a Greek priest, Nicolas Maldowan, who says that it fell with the quickness of lightning, and with a noise resembling a loud clap of thunder. "A fiery mass moving through the serene atmosphere in a descending direction, and coming to the ground with a stunning detonation which awoke the curate of Ohaba from his sleep," is another account of this meteor. The next morning, the 11th of October, the meteorite was found in an orchard where it had penetrated the moss-covered ground. It weighed about thirty pounds, is completely covered with the black rind peculiar to aerolites; the interior mass is greenish or bluish-grey, and in general appearance is not unlike the stone which fell at Château-Renard in 1841. It was submitted to analysis in Professor Wöhler's laboratory by Dr. Buckeisen.

A very fine fire-ball meteor or bolide was seen in many parts of France on the 29th of October, 1857, at six o'clock in the evening. This phenomenon, which was witnessed by Marshal Vaillant, M. Leverrier, and several others in Paris, appeared as a globe of light about the size of a cannon ball, moving rapidly from east to west, and leaving a long brilliant tail. The globe or nucleus was soon observed to divide into four or five balls of fire; the same was observed at Présigné, Sarthe, by Professor Paumard, who says that the fragments detached from the nucleus seemed to fall to the ground like the stars of a rocket. No explosions were heard either at Paris or elsewhere, nor have any aerolites been found and attributed to this meteor, but according to M. Petit (in the journal 'Cosmos,' 28th January, 1859), its height above the earth was 1244 leagues, or about 3732 miles—probably a most exaggerated estimate,—and its velocity seven and a half leagues per second.

On the 19th of May, 1858, at eight o'clock in the morning, a meteorite fell at Kakova, Temeser Banat, Hungary. The fall of this meteoric stone was attended with the usual phenomena. It has been examined by Professor Haidinger and Dr. Wöhler. A *small black cloud* was seen in the air, a hissing and a thunder-like noise heard to a distance of sixty-five English miles, a short and loud explosion at the moment when the stone —in a state of considerable heat—touched the ground, into which it penetrated to a depth of three inches. Count Coronini, Governor of the Banat, sent the stone to the Geological Institute of Vienna, where it is said to exist as it fell. But we have a specimen in the British Museum, weighing five ounces. When first picked up, it bore the resemblance of being a fragment of a larger mass; it has rounded angles and edges, and a *black cortical mass about half an inch thick,* extending into the interior in the shape of a vein. The composition of this stone is also well known. Minute particles of metallic iron are almost uniformly spread throughout the whole mass.

That a considerable number of aerolites which fall upon the earth are lost, probably for ever, will be seen from some of the preceding accounts, and also by what follows:—

On the 13th of September, 1858, a fine bolide was seen by M. de la Haye, between Rennes and St. Malo, France; also by M. Lecouturier at Bernières, near Vire, and by M. de la Tramblais, at Neuilly, near Paris. To the latter it appeared as a globe of fire crossing the heavens from south-east to north-west. Venus and Arcturus were the only stars visible, it being forty-eight minutes past six in the evening; the meteor lasted six or seven seconds at most. Its volume and brightness increased until it separated into several fragments, like immense sparks, which soon became extinguished. No explosions or other noises were heard by M. de la Tramblais. Baron de la Haye saw this meteor pass directly over his house, from south to north-west; its progression was slow enough to enable persons to be called out of the house to see it. A few seconds afterwards a violent explosion was heard, somewhat comparable to loud thunder. The sky was perfectly serene at the time. No aerolites of this meteor have, as far as I am aware, been yet discovered.

At about seven o'clock in the evening of the 9th of December, 1858, a meteorite fell at Clarac, canton of Montrejeau (Haute-Garonne), and caused considerable excitement in France. The meteor appeared first in the north-east, as a large fire-ball, which passed rapidly to the south-west, when it remained stationary for a moment. It then emitted a considerable volume of smoke and flame, three seconds after which a most violent detonation was heard, soon followed by a rumbling noise. Although a winter's morning was beginning to dawn, the little town of Aurignac was lighted up artificially, as it were, by the passage of this meteor. After the explosion nothing was observed in the sky but a *streak of smoke and a small cloud,* which marked out the direction of the meteor and the spot where it exploded. Two very large fragments, or aerolites, were thrown from this meteor. A large black stone, quite hot, fell near the church at Clarac, and broke through the thatched roof of a small granary belonging to a widow, Jeanne-Marie Capéron, who was at that moment at her door. When the stone was about to be picked up, it was found to be so hot that no one could touch it; some person present endeavoured to break it against another stone, and at the second stroke it was fractured into several pieces. The weather was calm and fine when the phenomenon occurred. A little time afterwards another fragment was picked up at Aussun, where it had penetrated into the ground to a depth of nearly two yards; it weighed ninety pounds; that which fell at Clarac weighed about sixteen or twenty pounds before it was broken by the peasants. I sent from Paris a complete description of this remarkable aerolite at the time of its fall.* It has been since examined by several eminent chemists. Both blocks present rounded forms, their surface is black and smooth, the interior is of a greyish substance. The stone attracts the magnet powerfully, and is easily broken into fragments. I shall refer to its chemical composition in another chapter. Both stones were eagerly broken up to supply specimens to the villagers and priests of Clarac and Aussun, shortly after the phenomenon occurred.

* See the 'Geologist,' vol. ii. no. 18, "Foreign Correspondence by Dr. T. L. Phipson."

In March and in August, 1859, some aerolites fell in North America; and in February, 1859, a fall appears to have occurred in France, on the 17th of that month. Here are two accounts of it:—

We read in the 'Mémorial d'Aix' (and the account is reproduced in the 'Ami des Sciences,' the 13th of March, 1859) the following details of a bolide observed by some of the inhabitants of the town of Aix:—"During the night of the 17th of February, 1859, about twelve o'clock, a bolide of considerable dimensions, appearing at least as large as the full moon, passed along the sky from S.S.E. to N.N.W., at an apparent height above the horizon of about 30°. The distance it appeared to run was also about 30° in length. The light of the moon (then full) did not seem to interfere at all with the immense intensity of that of the meteor, which neutralized it completely. Just as the meteor disappeared it was seen to burst, and sparks issued from it on the right and on the left, and instead of a brilliant globe there remained nothing but a very *red* light, about one-third the size of the globe of the meteor as first seen; this red light, instead of pursuing the path of the meteor, remained fixed for some seconds and then became extinguished without changing its place. About five minutes afterwards, when everything had assumed its usual aspect, a hollow sound, exceedingly distant, and like that of a heavy discharge of artillery afar off, reached the ear." No one knows where the aerolites, which must have accompanied the explosion of this meteor, happened to fall.

Another account of this phenomenon is reported in the 'Écho des Bouches du Rhône.' It appears that about half-past eleven o'clock at night, a person at Martigues saw a fire-ball, apparently in close proximity to the earth. It passed, with the rapidity of lightning, from south to north, and threw a vivid bluish light on all around. Continuing his walk for some minutes upon the Cours de Jonquières, the observer heard a distant detonation, which is stated to have lasted three minutes [?] at least. The night was remarkably fine, and the moon brilliant.

A most remarkable phenomenon occurred in Styria, on the 31st of July, 1859. It consisted in the fall of an exceedingly small fire-ball meteor, not much larger in appearance than an ordinary shooting star. We have a very complete description of the circumstance from Professor Haidinger:—On the 31st of July, 1859, about half-past nine o'clock in the evening, three inhabitants of the bourg of Montpreis, in Styria, saw a small luminous globe, very similar to a shooting star, and followed by a luminous streak in the heavens, fall directly to the earth, which it attained close to the château that exists in the locality. The fall was accompanied by a whistling or hissing noise in the air, and terminated by a *slight* detonation. The three observers, rushing to the spot where the meteor fell, immediately found a small cavity in the hard sandy soil, from which they extracted three small meteoric stones about the size of nuts, and a quantity of black powder. For five to eight seconds these stones continued in a *state of incandescence*, and it was necessary to allow upwards of a quarter of an hour to elapse before they could be touched without inflicting a burn. They appear to have been ordinary meteoric stones, covered with the usual black rind. The possessors would not give them up to be analysed. The details of this remarkable occurrence of the fall of an extremely small meteor, we owe to Herr Deschann, Conservator of the Museum of Laibach, in Carniola, and member of the Austrian Chamber of Deputies.

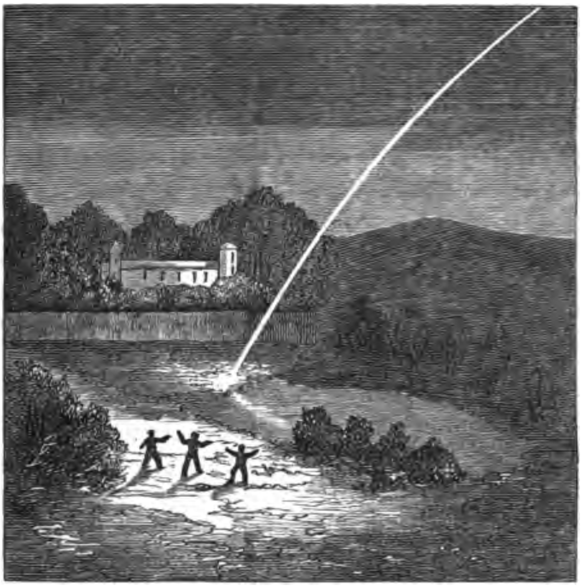


Fig. 3.

Fall of a small aerolite in Styria, on the 31st of July, 1859; from a drawing made shortly afterwards by Heinrich Goslar, engineer, of Montpreis, and communicated to the Author.

On the 3rd of February, 1860, an aerolite fell at Alessandria, in Italy. Its fall was accompanied by a violent detonation, *one minute* after which *a crackling noise* was heard in the atmosphere; it was *similar to the noise produced by the burning of green wood.* Herr Schrauf analysed one of the stones picked up on this occasion;* it was irregular in form, of uneven breakage, dark co-

* Poggendorff, 'Annalen,' ii., 1863; and the present work, Chap. XI.

loured, smooth on the exterior surface, etc. I shall give this analysis in a future chapter.

Several remarkable fire-ball meteors were witnessed in North America in May, July, and November, 1860. They are described in the journal 'Cosmos,' of the 18th of January, 1861:—On the 1st of May, 1860, at New Concord, Ohio, before one o'clock at noon, the sun being intense and the sky only slightly clouded, a luminous meteor, which appeared about the size of the full moon, was suddenly observed in the heavens. It burst with a violent explosion, and showered down a considerable number of aerolites. About thirty of these stones have been collected, the largest of which weighs 100 pounds English, and has a specific gravity equal to 3·54.

The next was seen on the 20th of July, 1860, about forty-five minutes past nine o'clock in the evening; it was observed, says the 'Cosmos,' by millions of persons in the United States, of the north and centre. Its apparent motion was very slow, and whilst at a height of about sixty kilometres (twelve leagues) it exploded *twice*, at least. No fragments of it had been discovered when the above was written.

A third meteor was seen at Denisville (New Jersey), at half-past nine in the morning, on the 15th of November, 1860. In spite of the bright sunshine, it appeared against the clear sky as a luminous globe, as large as the sun. At the moment of its apparition, it was about thirty leagues (one hundred and fifty kilometres) above the horizon. Its movement was estimated at nine leagues (forty-five kilometres) per second. It exploded several times, producing an intense noise, and a column of smoke, some three hundred and fifty yards wide, and several miles high. No stones have been found at present.*

One of the most celebrated falls that have occurred of late years is that which happened on the 14th of July, 1860, between two and half-past two in the afternoon, at Dhurmsala, in India. The aerolite in question fell with a most fearful noise, and terrified the inhabitants of the district not a little. Several fragments were picked up by the natives, and carried religiously away, with the impression that they had been thrown from the summit of the Himalayas by an invisible Divinity. Lord Canning forwarded some of these stones to the British Museum and to the Vienna Museum. Mr. J. R. Saunders also sent some of the stones to Europe. It appears that, soon after their fall, the stones *were intensely cold.*† They are ordinary earthy aerolites, having a specific gravity of 3·151, containing fragments of iron and iron pyrites; they have an uneven texture, and a pale grey colour.

We have seen another authentic fall described in the French journal 'Cosmos' as having happened on the 14th of February, 1861, at half-past six o'clock in the evening, at Tocane Saint-Apre, France. At that moment, a boy, named Duchazeau, entered his dwelling in a state of consternation. He said he had just seen a

* 'Cosmos,' 18th of January, 1861.

† This is a remarkable example of a stone arriving on the earth with a temperature approaching that of the interplanetary spaces. Aerolites containing much iron, a substance which conducts heat well, get thoroughly heated by their passage through the atmosphere. But the stony aerolites, containing less iron, conducting heat badly, preserve in their interior the temperature of the locality from which they fall; their surface only is heated, and generally fused. When these stones are large, the *excessive cold* of their interior portion, which must be nearly that of interplanetary space, is remarked; but when small, they remain hot for some time.

luminous meteor fall to the ground, in the market-place of the little town. He conducted his father, a veterinary surgeon, and his uncle, the Abbé Duchazeau, to the spot. They found the ground had been slightly cut up, and soon picked up a stone presenting all the characters of an aerolite. A fine rain was falling at the time. The stone only weighed about a quarter of an ounce, but was very hard, grey, and covered with the usual black rind. The Abbé Moigno (in the 'Cosmos') remarks on this occasion, that February is the month in which aerolites are of rarest occurrence, and that July appears to be that in which they are most abundant. Our readers will be better able to judge of this when they have perused the present volume.

According to an account published in the journals by Professor Joachin Balcells, of Barcelona, a perfect shower of meteoric stones fell on the 14th of May, 1861, at Canellos, near to Villanova, in Catalonia (Spain). Most of these aerolites penetrated so deeply into the soil that they could not be discovered. Those that fell upon the rocky surface were picked up; the heaviest of them weighs a little more than two pounds English, and has been forwarded to the museum at Madrid. It was, however, very difficult to procure even this specimen, for the peasants in the neighbourhood, believing that these stones, fallen from heaven, were destined to bring them good fortune, positively refused to give up one of them.

The journal, the 'Mémorial des Pyrénées,' furnishes us with the following extraordinary account, which I find reproduced in 'La Science pour Tous' of the 25th of September, 1862:—

On the 1st of August, 1862, as the members of the family Planté, of Morlans, were sitting quietly in the evening upon some stacks of corn, reposing themselves after a hard day's thrashing, they suddenly perceived that the roof of their cottage was on fire. A neighbour, coming up, assured them that when he was about a hundred yards from the place, *he saw a shooting star* fall upon the roof of the cottage, and a few moments afterwards the flames of the burning thatch appeared. The stone does not appear to have been sought for.

The remarkable fall of aerolites which happened in Belgium on the 7th of December, 1863, was perfectly observed and described in the 'Comptes Rendus' of the Paris Academy of Sciences, by M. Favart and M. Sæmann. The stones were analysed by my friend M. Pisani, Professor of Chemistry, in Paris, who afterwards examined those of Orgueil (1864), of which I shall speak presently.

The following are the particulars of the Belgian fall:—

The stones fell at Tourinnes-la-Grosse, three leagues to the south of Louvain, at a quarter past eleven o'clock in the morning. The fall was accompanied by a detonation which in this district was compared to the discharge of a forty-eight pounder cannon, whilst at two or three leagues from Tourinnes the noise was supposed to proceed from the explosion of some gunpowder manufactory. After the explosion a rushing noise was heard in the air; it lasted for nearly two minutes. An aerolite fell on the paved road of the village and broke into fragments, pushing in one of the pavement stones to a depth of some inches. The fragments, which were picked up soon after by the peasants, were still hot. The country people were much frightened by the phenomenon. It appears that two stones, at least, fell, the largest of which was presented to the Academy of

Sciences by M. Sæmann. The stone which fell upon the village pavement and broke into a number of pieces appears to have been the largest of the two. The second stone was found two days after the fall in a wood of firs, about three-quarters of a mile from Tourinnes. They are greyish-white, of fine texture, having a specific gravity of 3·52; they are covered with the usual black rind. Several workmen saw the stone fall at Tourinnes, and distinguished its form in the air; they said it appeared cylindrical, like a small post. The stone which fell in the little wood of firs struck one of the trees and made a deep mark upon the stem, which was flattened by it, but not cut in two.* It is possible that more stones of this Belgian fall will yet be found if sought for, as no less than four principal detonations were heard, each followed by a noise like the rolling fire of a line of musketry. The temperature of the fragments picked up immediately after their fall was estimated at about fifty degrees Centigrade. Some persons at Tourinnes on hearing the first explosion had time to get out of their houses and witness the fall of the stones, which circumstance leads me to believe that other stones must have fallen at some distance from Tourinnes. It is said that full details of this fall are given in the journal 'Les Mondes' of the 22nd of December, 1864, but up to the present time I have not been able to procure the journal of that date.

On the 10th of December, 1863, according to Pro-

* An aerolite was lately discovered in South-Western Australia, lying near to a large gum-tree which was stretched across the path, and had been cut in two by it. The date of the fall is not known. See my "Correspondance Anglaise" in the journal 'Cosmos,' September, 1864.

fessor Haidinger (Geol. Mag. vol. i.), an aerolite fell at Inly, near Trebizond. The accounts say that it fell about three o'clock in the morning, in an easterly direction, with a terrific explosion resembling the discharge of hundreds of cannon. Some fragments of it were forwarded to Vienna, and upon examination appear to be similar in nature to the meteorite of Orgueil, to which we shall now turn.

I have now come to the last fall of aerolites that has occurred up to the present time; I allude to the remarkable fall which occurred in France, near Orgueil, on the

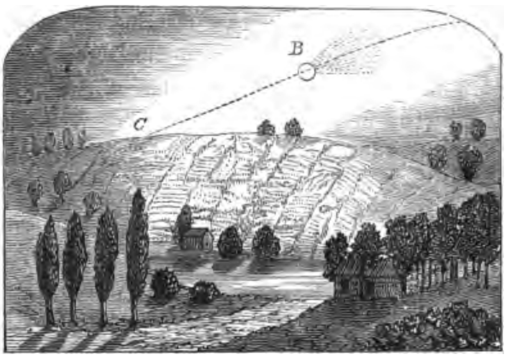



Fig. 4.

The Orgueil meteor as seen by M. Brongniart, member of the French Institute, 14th of May, 1864; from a pencil sketch and notes communicated to the Author.—B, position in which the fire-ball was first seen; C, point at which it disappeared very shortly afterwards below the horizon. The dotted line indicates its course in the heavens, the observer looking almost due south.

14th of May of the year 1864.* Thanks to the activity of my friend M. Daubreé, member of the Institute, the whole of the details relating to this important

* For a still more recent fall in India, see Appendix to this work.

phenomenon have been most carefully collected. The path of the meteor has been admirably made out by M. Laussedat; the stones themselves have been analysed by M. Cloez and M. Pisani.

On the 14th of May, M. Brongniart, the well-known botanist, was at his country-house at Gisors; at eight o'clock in the evening he perceived a very brilliant bolide; it appeared in the south, its motion was from west to east, and its elevation only fifteen to twenty degrees above the horizon, beneath which it soon disappeared. The next day all the newspapers of the south-west of France informed us that a splendid meteor had been seen at eight o'clock in the evening of the 14th, throughout France, from Paris to the Pyrenees. Near Paris it appeared about half the size of the moon, but towards the south, at Napoléon-Vendée, Poitiers, etc., it was as large as the full moon and higher in the sky. Near the villages of Nohic and Orgueil it was seen directly overhead; it appeared endowed with an oscillating and rotary motion, and finally exploded with a loud noise, throwing out numerous sparks and leaving behind it a white vapour. When the final explosion occurred the fragments of the meteor appeared to be projected in every direction, like a splendid firework; a cloud formed at the place, and all disappeared; some say, however, that the meteor, after the explosions had ceased, and most of its brilliant light disappeared, was seen to continue its course as a dark red globe which became extinguished in the distance. From eighty seconds to five minutes (according to the positions of the different observers), after the apparition and explosion of the meteor, a deep rolling sound, comparable to that of artillery, was heard, and continued for some time; this noise had no sooner ceased than a sharp shower of meteoric stones occurred. They fell obliquely from west to east, in the narrow space comprised between the villages of Nohic, Orgueil, Mont-Béqui, and Campsas. They were hot at the moment they arrived at the ground. One which fell into the granary of a peasant burnt his hand when he picked it up; others, which fell upon the grass burnt it, producing yellow marks round the spots where they were found lying. The stones are similar in appearance to other aerolites, having the ordinary black crust, which can be produced upon fragments of the interior when heated white-hot before the blowpipe. But they are very remarkable by the fact that they contain as much as five per cent. of *carbon*. It is only the fourth time that this element has been met with in aerolites. The stones are somewhat fragile, and give dark streaks upon paper. I shall refer to their chemical composition in the proper place. The height of this meteor in the atmosphere at the moment it became visible was fifty kilometres (ten leagues). At the moment it exploded over the village of Nohic it was sixteen to twenty kilometres (four or five leagues) high, about four times the height of Mont Blanc. These data have been carefully ascertained by M. Laussedat,* who determined the rate of transmission of the meteor through the air to be five leagues per second.

NOTE.—Since the above was written, M. Lespiault has called our attention to a very brilliant fire-ball which appeared in the middle of the day, at twenty minutes past twelve o'clock, on the 24th of September, 1864, near Mont-de-Marsan, in France; it appeared like a

* 'Comptes Rendus' of the Academy, 1864.

huge globe of fire as large as a bomb-shell, and burst with a most terrific report which lasted about ten seconds, and was heard perfectly at Nérac; the report is compared to that of twenty pieces of cannon discharged at the same moment. No aerolites have yet been found in the district ('Comptes Rendus,' 26th of September and 3rd of October, 1864). For a fall that has occurred in 1865, see Appendix.

# CHAPTER X.

## A FEW WORDS ON SOME ANCIENT FALLS OF AEROLITES.

It will be easily conceived that the magnificent phenomena with which we have been occupied, are not merely occurrences of modern times, but have happened in every *historical* period. By their noise and brilliancy these meteors have not failed to attract attention in olden times; so that we find here and there allusions to them in the works of ancient authors. The question to examine here, in the first place, however, is that of the existence of *antehistoric* aerolites. Olbers appears to have been the first to allude to the fact that "*no fossil meteoric stones*" had ever been found, either in the secondary or tertiary formations:—In Schumacher's 'Journal' (1838, p. 329) he asks, "May we conclude from this circumstance, that previous to the present and last modification of the earth's surface no meteoric stones fell upon it, although at the present time it appears probable, from the researches of Schreibers, that about 700 fall annually?" To which Alexander von Humboldt has replied (in his 'Cosmos,' vol. i. 119) by alluding to certain metallic masses, containing iron and nickel, which have been found in the gold-washing district at Petropawlowsk, eighty miles south-east of Kusnezk, Siberia, imbedded thirty-one feet in the ground; and to similar masses, very much like meteoric stones, discovered more recently in the Western Carpathians, at Szlaniez, in the mountain chain of Magura. The latter, according to Berzelius ('Jahresbericht,' vol. vii.), were so considerable that they have been employed in the forges.

To this we may add that Mr. E. W. Binney, an English geologist, has described in the 'Transactions of the Literary and Philosophical Society of Manchester' (vol. ix.), the occurrence of three stones, probably meteorites, which were met with in the coal formation of Lancashire.

This is all, as far as I am aware, that has been observed concerning the existence of antediluvian aerolites. The composition of these interesting stones—whether they be of the stony variety or in the state of metallic masses—is so well ascertained that it will be sufficient in future to submit a stone found in any strata to the test of chemical analysis, in order to be at once assured whether it has had a meteoric origin or not. Up to the present time it appears extremely doubtful that any meteoric stones have been met with in the more ancient strata of the earth, and *consequently we may conclude*, for the present, with the greatest probability, *that falls of aerolites are not more ancient than the existence of our present active volcanoes.*

We can trace more or less authentic records of fallen stones, or aerolites, as far back as some 3000 years.

I allude to the few following records purely for their historical interest, as showing that fire-ball meteors and aerolites have been observed in all ages of the human race, and by all nations. The facts recorded are often somewhat scanty, or obscurely described, and their authenticity is not always to be relied upon. They have little or no scientific interest, save that which attaches to the history of all natural observation, however remote and however obscure.

The famous Parian marbles, engraved in the island of Paros (still celebrated for its fine marble), about the year 264 before the commencement of the Christian era, constitute a valuable chronicle of Grecian history, going back as far as 1582 before Christ. These valuable relics of antiquity (which are now, I believe, in the possession of the University of Oxford?) make several allusions to what we may safely suppose to have been falls of aerolites, often of great size. According to the eighteenth and nineteenth lines of these Chronicles of the Parian Marbles, an aerolite appears to have fallen in Crete about the year 1478 B.C.

According to the ancient historian Pausanias, some stones preserved in the Bœotian town of Orchomenos fell from the skies about the year 1200 B.C.

The twenty-second line of the Parian Chronicles leads us to believe that a metallic mass was seen to fall upon Mount Ida, in Crete, about the year 1168 B.C.

It is almost impossible to assign an approximate date to the meteoric fall which is alluded to in a remarkably clear manner by Herodotus, the "father of history" (lib. iv. cap. v. and vii.). In plain English the interpretation of this well-known passage is, that the first of the Scythians, Targitas, had three sons, who happened one day to witness the fall of a splendid aerolite. The eldest son approached it, but it was so hot he could not touch it; the second followed, but it burnt his fingers likewise; at last, after some time, the youngest son, Colaxaïs, approached, and (the aerolite having by this time cooled) he carried it off. "The two elders, *understanding what was meant by this prodigy,* gave up the kingdom to the youngest." Herodotus is supposed to have been born about 484 B.C., but it is impossible to assign a date to this anecdote relating to the origin of the Scythian nation.

The following examples of ancient falls are likewise enveloped in the obscurity of forgotten times:—The "Mother of the Gods" was worshipped at Pessinus, in Galatia, under the form of a *stone,* which was said to have *fallen there from heaven;* this stone, in consequence of a treaty with Attalus, king of Pergamus, was solemnly brought to Rome by Publius Scipio Nasica, about 204 B.C., and placed in the temple of Cybele. The sun was worshipped at Emisa, in Syria, under the form of a *large black stone,* of a conical shape, which, as the people about the temple reported, *had fallen upon the earth.* It was afterwards brought with great pomp to Rome, by Elagabalus, who had been high-priest of the temple, and the description of it which is given by the ancient historian Herodian (lib. v.) accords somewhat with the general appearance of a meteoric stone.

The stones spoken of by Livy (i. 30) as having fallen during the reign of Tullus Hostilius (about 654 B.C.) on the Alban mount, not far from Rome,—stones which were said to fall in a perfect shower,—appear to have been volcanic *rapilli,* or pumice; for, as Humboldt justly remarks ('Cosmos,' vol. i.), this Mount Albanus was at that time a volcano in activity, or not wholly extinguished. So that historians must not refer the term *lapidibus pluit* to aerolites, unless the chances of volcanic products being present in the locality are absent.

Of all the ancient falls of aerolites on record, one of the most authentic is that which occurred about the year 465 B.C., at Ægos Potamos in the Hellespont, near the modern Gallipoli. The stone which fell is described by Plutarch, in his 'Life of Lysander,'* it is also mentioned by Pliny the elder (book ii.), who says it was to be seen in his time (that is, 500 years afterwards); that it was of colossal size, of a dark colour, and that its fall was accompanied by a meteor. This fall is also recorded on the Parian marbles. Diogenes of Apollonia speaks of it in these terms:—"Stars that are invisible, and consequently have no name, move in space together with those that are visible. These invisible stars frequently fall to the earth and are extinguished, as *the stony star which fell burning at Ægos Potamos,*"—a passage which indicates that some of the ancients had very clear notions concerning fire-ball meteors and aerolites. The stone of Ægos Potamos fell about the year in which Socrates was born; its size was described as that of two millstones, and its weight to that of a full waggon-load. The African traveller Brown sought for it, but without success.

Besides these, there are a number of falls recorded by the Chinese, whose reports extend back to the year 644 B.C., or 179 years before the fall of the aerolite of Ægos Potamos just mentioned, and for which I must refer to the works of De Guignes, Abel Rémusat, and E. Biot.† M. Rémusat shows that the Chinese and Japanese noted carefully everything connected with meteoric phenomena. According to the same author, there

* The passage is given in the Appendix to this volume.

† See also Chladni's "Catalogue," Ann. de Chim., 1826, p. 253 *et seq.*, and Rémusat's translation of the Chinese work of 'Ma-tuan-lin,' written in the thirteenth century.

is a Mongolian tradition concerning a black fragment of rock, forty feet in height, which is said to have fallen from heaven on a plain near the source of the Great Yellow River, in Western China ('Journal de Physique,' May, 1819). The Mongols call it *Khadasut filao*, or rock of the pole (polar rock), and assert that it fell from a fiery meteor; the date cannot be ascertained.

This is also the place to allude to the iron-mass found in Siberia in 1776, by the travelling naturalist, Dr. Pallas. The meteoric nature of this mass has been perfectly ascertained, as well as that of several other blocks of a similar nature discovered since. Dr. Pallas found this metallic mass (so interesting on account of Chladni's speculations concerning it, at a time when the philosophers of Europe had not yet turned their attention to the subject of aerolites) quite isolated, high up on a slate mountain, near the river Jenesei. The Tartars possess a tradition, according to which this mass was seen to fall from the skies, and it has been venerated by them ever since. In 1779 it was removed to the town of Krasnojarsk; it then weighed 1400 pounds; its form was irregular, its texture not solid but spongy, the cells in it containing granular olivine. Analysed by Howard, it gave seventeen per cent. of nickel; Klaproth and John found less nickel, and Laugier found silica, magnesia, sulphur, and chrome also. There is a fragment weighing seven pounds in the British Museum collection; the iron is exceedingly malleable, and may even be cut with a knife. Dr. Pallas transmitted to England the fragment now in the British Museum. The fall of this metallic mass must have happened in the most remote antiquity.

Several such metallic masses have been met with on various parts of the earth's *surface*, some have a porous structure, like the specimen just alluded to, others are more compact, and resemble the iron which fell at Agram in 1751 (see *ante*). There is no longer any doubt as to their meteoric nature, for most of them have been submitted to the most rigorous chemical investigation. To this category belongs, for instance, the iron meteoric mass found about 500 miles north of Buenos Ayres, in the province of Santiago del Estero, described in Spanish in the 'Philosophical Transactions' for 1788, by Señor Rubin de Celis. This mass was

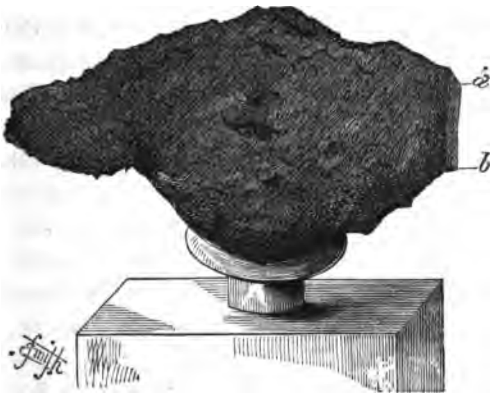



Fig. 5.

The meteoric iron mass of Tucaman, Otumpa, South America, weighing 1400 pounds; one-twentieth of the original. From a drawing, by the Author, of the specimen in the British Museum. —*a*, *b*, surface cut and polished.

estimated to weigh about thirteen tons; it was half buried in the ground when discovered. It was analysed by Proust and Howard, who found ten per cent. of nickel and ninety of iron. (Many of these older analyses are incomplete.) A similar mass, found at the Cape of

Good Hope, (and described by Barrow as an artificial production, 'Travels in Africa,') has been investigated by Van Marum, as a portion of it was sent to the Museum of Haarlem. A large iron mass, found in 1788, at Tucaman, Otumpa, Argentine Republic (South America), is preserved in the British Museum. A sketch of it is annexed; its weight is 1400 pounds. A still larger mass has recently been discovered in Australia. (See Appendix.)

Other metallic masses of meteoric origin have been met with in Mexico, in Bohemia, and Hungary (Lenarto), on the right bank of the Senegal, in North America, in Poland, Germany, etc. etc. Near Baffin's Bay, at a place called Sauwallik, there are two masses, one compact, and the other stony, but containing iron, discovered by Captain Ross; the Esquimaux have been long in the habit of making knives of this meteoric iron,—they beat

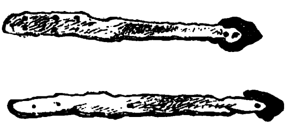


Fig. 6.

Esquimaux knives, made of meteoric iron found in Greenland; one-eighth of the natural size; from a drawing by the Author.

it into flat pieces, and insert the blade thus produced between two pieces of bone.

Herodotus, whom we have quoted above, must have been born about 484 B.C., and he assures us that the most ancient of the Grecian poets, Homer, was about 400 years before his time, so that if we take for granted the statement of Herodotus, Homer must have flourished about 884 B.C., or 2748 years ago. Now, in the 'Iliad' (canto xv. 18–22) where Jupiter reproaches Juno with having caused the defeat of the Trojans, there is a passage concerning "*two anvils* :"—"Dost thou not remember," he adds, "when thou wast hanging in the heavens, and that I had attached to thy feet *two anvils?* etc. . . ."

It appears, according to MM. Miller and Haidinger, that these two "anvils" were aerolites. Eusthathe, Archbishop of Salonica, living in the twelfth century, says that these "anvils" of which Homer speaks were exhibited in his time, and the tradition was that they had fallen from the skies.* This, if we may believe it authentic, would be the oldest record known of an aerolitic mass.

A great mass of iron, weighing about 14,000 pounds, was discovered in 1816, some fifty leagues from Bahia, in the Brazils; a fragment of it was analysed by Dr. Wollaston, and yielded four per cent. of nickel. There is no doubt about its being a meteoric mass that may have fallen only a few years ago, or, may be, before the time of Homer.

The foregoing instances will suffice to show that aerolites have fallen in all ages of man's history; there are several other passages of ancient Greek and Latin authors which could be brought forward here, if I thought that by so doing I could add to the interest of the present work. I cannot, however, conclude this chapter without alluding to one or two remarkable falls which occurred in the Middle Ages.

The most remarkable of the latter is perhaps that which occurred at Ensisheim, in Alsace, on the 7th of November, 1492. The Emperor Maximilian, being there at the time, ordered an account of the event to be

* Dr. Hoefer, in the journal 'Cosmos,' 17th of November, 1864.

written. The meteoric phenomena, explosions, great light, rattling and hissing sounds in the air, etc., are perfectly described. This stone fell in the middle of a wheat-field, and penetrated five or six feet into the ground. An old chronicle of the period gives the following account,* which I abridge :—

On Wednesday, the 7th of November, 1492, *between eleven o'clock and noon,* there was a loud peal of thunder and a prolonged confused noise, which was heard to a great distance, and a stone fell from the air at Ensisheim, which weighed two hundred and sixty pounds, There a child saw it strike in a field of wheat towards the Rhine and Inn, near Gisgard. It did no harm except that it made a hole there. Many pieces were broken from it, but the largest was placed in the church, for it was considered a miracle. Trithemius, the learned author of the 'Hirsaugiensian Annals,' speaks of the same fall; he says the stone weighed two hundred and fifty-five pounds, and that its fall was so violent that it broke into two pieces, the largest of which was suspended to a chain at the door of the church of Ensisheim. Paul Lang, another writer, who, like Trithemius, lived at the time of the fall, says that on the 7th of November, 1492, there arose a furious storm, and whilst the thunder roared and the heavens appeared on fire, a stone of enormous size fell at Ensisheim. There is a fragment of this celebrated aerolite, weighing one pound, in the British Museum, and another fragment preserved in the Museum of the Jardin des Plantes, Paris. Some of it was to be seen in the Library at Colmar; but whether any fragment still exists in the church at Ensisheim I do not know.

* 'Encyclopædia Britannica,' xiv. 629.

A great shower of aerolites occurred on the plain of Lombardy, in 1511. It is mentioned in the 'Commentary' of Surius, a Carthusian monk of Cologne, and again by Cardan in his work 'De Rerum Varietate.' The stones fell at Crema, on the river Adda, not far from Milan, at five o'clock in the evening of the 4th of September, 1511. The largest weighed about one hundred and twenty pounds; they were very hard, and smelt of sulphur at the time of the fall. This fall is also mentioned by Petrus Martyr, in his 'Opus Epistolarum.' The stones were estimated at about 1120 in number; several weighed many pounds, and one of them in falling struck an ecclesiastic and killed him on the spot. Birds, sheep, and even some fish were killed by this fall. It is curious to note that before this meteoric shower, no stones were ever noticed on the Plain of Crema; after the fall about 1120 were observed, all iron-grey, heavy, and having a sulphureous odour. When Jerome Cardan speaks of this fall as having occurred in 1510, he errs by a year, and his error is reproduced in the 'Encyclopædia Britannica.' At the time of the fall, Cardan was only nine or ten years of age. The shower was accompanied by the usual meteoric phenomena, namely a brilliant fire-ball meteor, a dense black cloud from whence the explosions issued, etc.

If we approach more modern times, we still meet with the same curious accounts of meteoric falls. It is perhaps a remarkable coincidence that in 1650 another monk was killed near Milan by the fall of a meteoric stone.* In the year 1674, two Swedish sailors on board ship were likewise killed, according to Humboldt, by the fall of an aerolite. I find in Chladni's catalogue

* In other countries the victim might have been a peasant.

(Ann. de Chim. 1826, p. 257,) to which I may refer for *indications* of about two hundred and eighty ancient and modern falls, that on the 18th of May, 1680, some meteoric stones fell in London, and that the fall is mentioned by Mr. Edward King.* In the catalogue of Chladni there are twelve allusions to *metallic* aerolites (iron masses) seen to fall, three others are mentioned in the present work,—making in all fifteen falls of *metallic* masses, all the others being stony aerolites. But we shall see presently that this apparent distinction is highly artificial; that all aerolites, whether stony or metallic in appearance, are essentially of the same chemical nature, and in bringing forward in another chapter the composition of these meteoric stones, it will be noticed that there is a gradual transition from the purely metallic to the most stony in appearance,—a fact which, of course, forces us to attribute *a common origin* to all aerolites.

Chladni's catalogue was compiled with a great amount of labour and research, and constitutes a lasting monument of the author's industry and learning. There exist in it, however, certain gaps, which more modern research has filled up. Thus, between the year 1622, when, according to Chladni, a stone fell in Devonshire on the 10th of January, and the year 1628, when an aerolite fell in Berkshire on the 9th of April, there is the important observation of the astronomer Gassendi, who saw "a flaming stone, apparently four feet in diameter," fall on Mount Vaision, in Provence, on the 27th of November, 1627, about ten o'clock in the morning. The sky was

* This author published a work, entitled 'Remarks upon Stones said to have fallen from the Clouds,' which I have not been able to procure.

clear at the time. The meteor was surrounded, he tells us, by a luminous circle of different colours; and the fall of the stone, which was hard and black, and weighed fifty-nine pounds, was accompanied by a noise like the discharge of artillery.

The last fall I shall notice here is that of some enormous stones, two and three hundred pounds in weight, which fell at Verona, with a tremendous noise, on the 19th or 21st of June, 1668. They fell during the night, the weather being perfectly serene at the time; and the fall was witnessed by several hundred people. Valisnieri, Montanari, and other writers, have given accounts of the phenomenon.

# CHAPTER XI.

## ON THE CHEMICAL COMPOSITION OF AEROLITES.

We now come to speak of the composition of aerolites. And this is a chapter which I will use my best endeavours to render interesting to the general reader; for it relates to that portion of the history of meteors which is, without doubt, the most important, and, as I trust will be clearly seen in the sequel, one of the chief means by which we may be enabled to account for the *origin* of these remarkable phenomena. A considerable number of aerolites seen to fall, as related in the foregoing chapters, have been submitted to most accurate and minute chemical investigation by some of the most eminent analytical chemists, and their composition may be said to be thoroughly well known. Instead of bringing forward here all the analyses of these interesting bodies which I have been able to collect, it will be preferable, doubtless, to produce only a sufficient number of characteristic analyses, which illustrate, at a glance, the general composition of meteorites, and will be the more interesting, as they relate to falls of which particular mention has already been made in these pages.

A few general remarks will suffice to enable the reader to appreciate the analyses in question, though they will give no idea of the labour and patience with which the numerical results have been obtained.*

It is a curious fact that *metallic iron*, a metal which is daily in the hands of millions of men, is exceedingly rare in nature. Of ironstones or iron-ores (oxides of iron, carbonate of iron, silicate of iron, etc.) there is a great abundance, but iron *in the metallic state* is one of the greatest rarities of the mineral world. It is true that it has occasionally been met with, sometimes in the products of the burning of a coal mine, once in a mica-slate rock, once in an ironstone conglomerate, in the lava of Auvergne, and in microscopic grains in some basalts, etc.; but it is, nevertheless, of very rare occurrence. Now, metallic iron is invariably present in aerolites, in quantities which vary from ninety per cent., and upwards, to 0·1 per cent., and even less. The iron of meteorites or, as it is sometimes called, "meteoric iron," is not pure; it *always* contains a certain amount of *nickel*, generally eight or ten per cent., with small quantities of cobalt, copper, tin, and chrome. The large masses of metallic iron found from time to time upon the surface of the earth, and the aerolites of Agram, Braunau, etc., present this composition, which belongs to no other known substance. And when the fragments of meteoric iron, dispersed through aerolites of a more or less earthy nature, are carefully extracted by a magnet, and submit-

* It is to Howard, Klaproth, Thenard, Vauquelin, Proust, Berzelius, Stromeyer, Laugier, Dufrénoy, Gustav Rose, Heinrich Rose, Boussingault, Rammelsberg, Shepard, Wöhler, Baumhauer, Damour, Pisani, Cloez, and several other eminent chemists, that we owe our chemical and mineralogical knowledge of aerolites. The names of so many well-known philosophers clearly show what interest attaches to this portion of our subject.

ted to analysis by themselves, they give the same composition, that is, about ninety of iron, about eight or ten of nickel, etc.

The other constituents of aerolites are certain mineral substances (silicates), not unlike the silicates which are found in our volcanic rocks. Of these, *olivine** (silicate of magnesia, containing more or less protoxide of iron, and soluble in acids) is *invariably* present. It is a remarkable fact that this olivine, which is always to be found in aerolites, even in those of a metallic character, where it forms grains disseminated in the iron or lodged in its cavities, is a mineral highly characteristic of volcanic rocks. It is met with abundantly in lavas and basalts (ancient lavas), but in no other rocks of the earth, unless here and there, as a rare substance, in rocks which have been affected by volcanic action. It will be seen, among the analyses given in this chapter, that the olivine extracted from meteoric masses is similar to that of Mount Vesuvius.

Other mineral silicates detected in aerolites, more especially by Gustav Rose and Rammelsberg, belong also to a class of substances which constitute mostly the eruptive and volcanic rocks of our earth; such as *augite* or *hornblende*, and a kind of *felspar* (which may be *labradorite*, *anorthite*, or *albite*).

The next substance we have to consider is *schreibersite*, a compound of phosphorus, iron, and nickel, (a phosphide of iron and nickel,) which has never been found except in meteorites. It appears to occur in all of them without exception; but the quantity present is never very great, and often too small to be estimated. This substance has become still more interesting since it was

* Sometimes called *peridot* or *chrysolite*.

formed artificially in an experiment made for that purpose, in 1863, by M. Faye,—an experiment to which I shall refer again.

*Magnetic pyrites* (magnetic sulphide of iron) is often present in aerolites, usually in small quantities. Schreibersite has often been mistaken for it. Sometimes the sulphide of iron in aerolites is not attracted by the magnet. It is curious to note that this magnetic pyrites is also met with in the lava of Vesuvius; but it occurs in other rocks.

Small quantities of *chrome-iron* (oxide of chrome with protoxide of iron) are usually met with in aerolites; it remains as a residue, with schreibersite, etc., when the meteorites are dissolved in an acid.

Of late years, *carbon*, first met with by Thenard, in the Alais meteorite, has been found in many others; it is usually present in the pure state, and likewise in the form of a *hydrocarbon*, somewhat similar to the waxy substance, paraffine, and perhaps also in some other form; but in very small quantities.

*Magnetic oxide of iron* is usually present in all meteorites.

These are all the substances that have been met with in aerolites; it will be observed that they are not very numerous, and, further, that aerolites always contain them.

Indeed, meteorites may be looked upon, chemically, as being always of the same composition, their structure alone varying, and one or more of the ingredients found in them predominating over the others, according to the variety of meteorite under consideration. Thus the *metallic iron* may vary from 0·1 to 96 per cent.; but it is always accompanied by olivine, etc. In the same manner, the olivine itself is seen to vary from 1, 2, 3, to 90 per cent.; thought it is most usually present to the extent of about at 45 to 50 per cent.

Since the introduction of spectrum analysis, by which the alkalies and alkaline earths are so easily recognized by the lines they produce in the spectrum of a flame into which compounds of these metals are volatilized, both *lithia* and *strontia* have been detected, by Engelbach, in the meteorite which fell at the Cape.

The simple substances (*chemical elements*), therefore, that have been detected in aerolites, are *oxygen, sulphur, phosphorus, carbon, silicium,* (*arsenic?*) (*chlorine?*) *aluminium, magnesium, calcium, potassium, sodium, lithium, strontium, iron, nickel, cobalt, chromium, manganese, copper, tin,* and *titanium,*—in all, twenty or twenty-two elements, not quite one-third of the number known to exist. The *proximate* principles of aerolites have been thus ingeniously classed by Rammelsberg, and given by Humboldt:*—

| | |
|---|---|
| *a.* Metallic | Nickel-iron.<br>Schreibersite (a combination of phosphorus, nickel, and iron).<br>Sulphide of iron (magnetic or not). |
| *b.* Oxydized. | Magnetic iron oxide.<br>Chrome iron. |
| *c.* Silicates. | Soluble in acids. Olivine.<br>Insoluble in acids. Felspars and augites. |

The nature of the elements invariably contained in meteorites, and the peculiar grouping of these elements (*i. e.* the compounds formed by them in aerolites), enable us at once to detect, by chemical analyses, a meteoric substance from any other natural product.

* I have slightly modified this very simple classification. Compare his 'Cosmos,' vol. iv.

Hence the certainty with which a meteoric origin has been attributed to those metallic masses occasionally met with on the surface of the globe, to the fall of which no dates can be assigned.

The further remarks that I have to offer upon the composition of aerolites will be appended to the analyses which follow. In these analyses I begin with aerolites containing most metallic iron, and terminate with those in which the metallic iron appears to have almost or quite disappeared.

### I.—METALLIC IRON, EIGHTY TO NINETY PER CENT. AND UPWARDS.

A. Aerolite which fell at Braunau, on the 14th of July, 1847, analysed by Fischer and Duflos (Millon, 'Annuaire de Chimie,' 1848 and 1849) :—

| | |
|---|---|
| Iron | 91·862 |
| Nickel | 5·517 |
| Cobalt | 0·529 |
| Copper, manganese, arsenic, calcium, magnesium, silicium, carbon, chlorine, and sulphur | 2·072 |
| | 100·000 |

*Observations.*—We have already noticed that this meteorite had a very crystalline structure; moreover, it contains nucleoles and lamellæ of what is now known as *schreibersite*, a phosphide of iron and nickel, which the authors succeeded in isolating from the rest, and which gave them the following composition :—

| | |
|---|---|
| Iron | 56·430 |
| Nickel | 25·015 |
| Phosphorus | 11·722 |
| Chrome | 2·850 |
| Carbon | 1·156 |
| Silica | 0·985 |
| | 98·158 |

This schreibersite is disseminated through the whole mass of the aerolite, giving it a peculiar crystalline appearance. As we have already stated, it is present more or less in all aerolites. It appears to have been often mistaken for iron-pyrites (magnetic pyrites). Pure schreibersite probably contains iron 55·36, nickel 29·17, and phosphorus 15·47=100. (We shall return once more to this interesting substance. For further details upon its composition see Dana's 'Mineralogy,' second part, p. 53, and Appendix, p. 511, for some analyses by Dr. Lawrence Smith.) The substance called *dyslytite* by Professor Shepard is another compound, consisting of phosphorus, iron, nickel, and magnesium, in form like a blackish-brown powder; it is supposed, like schreibersite, to be peculiar to aerolites, in which there is usually from 0·25 to 2·25 per cent. It is as yet very little known, and is very probably impure schreibersite.

B. Meteoric iron of Bahia, found, in 1784, near Bahia, Brazils; analysed by Wöhler and Martius (Repert. de Chim. 1861):—

| | |
|---|---|
| Iron | 88·48 |
| Nickel and cobalt | 8·59 |
| Schreibersite | 0·37 |
| Carbon (with a certain white substance, the nature of which is [was then] unknown) | 0·07 |
| Loss | 1·96 |
| | 10·000 |

*Observations.*—Specific gravity equal to 7·69. Hardness equal to that of steel. The iron of this meteorite is in what is termed the *passive state,* that is, not liable to rust, and attacked with difficulty by acids,—a state which is not uncommon to meteoric iron; the latter, however, does *not always* possess this property.

C. Meteoric iron found in Mexico, analysed by the same (*loc. cit.*) :—

| | |
|---|---|
| Iron | 89·22 |
| Nickel and cobalt | 9·51 |
| Phosphorus | 0·20 |
| Schreibersite | 0·06 |
| Carbon and white substance | 0·24 |
| | 99·23 |

*Observations.*—Specific gravity equal to 7·85. The iron in this meteorite is *not* in the "passive state," but rusted on the surface. This circumstance may perhaps be connected with the comparatively small amount of schreibersite present.

D. Meteoric iron found in Siberia, analysed by Berzelius (Poggendorff, 'Annalen,' 1834) :—

| | |
|---|---|
| Iron | 88·042 |
| Nickel | 10·732 |
| Cobalt | 0·455 |
| Manganese | 0·132 |
| Copper and tin | 0·066 |
| Magnesium | 0·050 |
| Carbon | 0·043 |
| Sulphur | traces |
| Phosphide of iron and nickel | " |
| Chrome iron | " |
| Silica (residue) | 0·480 |
| | 100·000 |

*Observations.*—This excellent analysis is that of the celebrated iron discovered by Dr. Pallas in Siberia. It will be remembered that these metallic meteorites generally contain grains of olivine; now the grains of olivine extracted from this meteoric iron mass, discovered by Pallas, have been analysed by Walmstedt, and the same chemist analysed the olivine of Mount Somma (Vesuvius); here are the two results:—

| | *Olivine of Pallas's Meteorite.* | *Olivine of Vesuvius.* |
|---|---|---|
| Silica | 40·83 | 40·08 |
| Magnesia | 47·74 | 44·22 |
| Protoxide of iron | 11·53 | 15·26 |
| Alumina | trace | 0·18 |
| Oxide of manganese | 0·29 | 0·48 |
| Lime | trace | trace |
| | 100·39 | 100·24 |

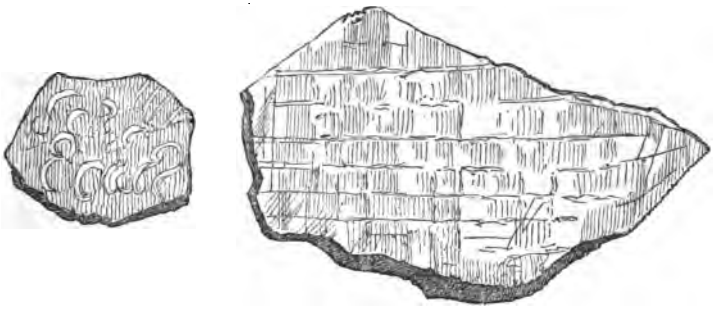
These two substances are, therefore, almost identical in composition,—a most interesting fact, serving, with many others, to show the close connection which exists between meteorites and modern volcanic products.

E. Meteorite found at Santa Rosa (Mexico), analysed by Wichelhaus (Pogg. Ann. 1863):—

| | |
|---|---|
| Iron | 96·072 |
| Nickel | 3·263 |
| Cobalt | 0·550 |
| Phosphorus | 1·046 |
| | 100·931 |

*Observations.*—Like all meteorites *found*, the date of its fall is unknown; there are many large blocks of it in the province. The iron mass is covered with rust, therefore it is not in the "passive state." It is almost entirely soluble in hydrochloric acid, the residue amounting only to 1·262 per cent., and consisting of schreibersite.

Many meteoric irons, when slightly attacked on the surface by an acid, show certain crystalline figures or lines, which have been called "Widmannstäten figures." This Mexican iron shows something of the same sort, only the lines are straight instead of curved or angular, and appear, when the acid is wiped off, like very thin streaks diverging from one or more points of the surface. I give here some sketches of these figures, as seen



Figs. 7 and 8.

Widmannstäten figures on meteoric iron (from drawings, by the author, of specimens in the British Museum).

on some specimens of meteoric iron preserved in the British Museum.

F.—Meteoric iron of Tula, (found) analysed by Auerbach (Répertoire de Chim., 1863) :—

The paper by Auerbach is a most important study of this remarkable mass found at Tula. The author shows that the stony portions found in the cavities of the metallic mass have the same composition as ordinary stony aerolites. The iron itself contains :—

| | |
|---|---|
| Schreibersite | 0·90 |
| Tin | 0·07 |
| Nickel | 2·63 |
| Iron | 96·40 |
| | 100·00 |

Whilst the stony portions consist of—

| | |
|---|---|
| Nickeliferous iron | 16·70 |
| Chrome iron | 0·11 |
| Soluble silicate (olivine) | 72·98 |
| Insoluble silicate (labradorite and augite ?) | 10·21 |
| Sulphide of iron | traces |
| | 100·00 |

*Note.*—Some of the metallic meteoric masses have been shown to contain *chlorine* combined with the iron, in the state of chloride of iron. A meteoric iron discovered in Alabama gave Mr. Hayes—

| | |
|---|---|
| Iron | 83·572 |
| Nickel | 12·665 |
| Chlorine | 0·907 |
| Magnetic pyrites | 2·395 |
| | 99·536 |

Chloride of iron constantly exudes from such meteorites, causing them to become damp, and to stain the paper in which they are enveloped. This analysis by Hayes is given in Berzelius (Rapp. Ann., 1847). Mr. Shepard supposes that the chlorine is derived from a small quantity of chloride of sodium contained in the aerolite, but we have no authority for this assertion. The existence of chlorine in many meteoric stones is another fact which connects them with certain volcanic products.

G.—Meteorite found at Zacatecas. Analysis by Bergmann (Millon, 'Annuaire de Chimie,' 1850) :—

| | |
|---|---|
| Iron | 85·09 |
| Nickel | 9·89 |
| Cobalt | 0·66 |
| Copper | 0·03 |
| Magnesium | 0·18 |
| Carbon | 0·16 |

| | |
|---|---|
| Carbon with iron | 0·33 |
| Phosphide of iron and nickel | 1·65 |
| Chrome iron | 1·48 |
| Manganese | traces |
| Sulphur | 0·84 |
| | 100·31 |

*Observations.*—Specific gravity = 7·489. There are nine *equivalents* of iron for one equivalent of nickel, as in Rammelsberg's analysis of the aerolite of Nordhausen, given further on; and this appears to be the proportion in which these two metals are always present in aerolites.

H.—Meteoric iron found at Arva, analysed by Patera and Loewe (Millon, 'Annuaire,' 1850):—

*Patera's Analyses.*

| | | | |
|---|---|---|---|
| Iron | 89·42 | 93·13 | 94·12 |
| Nickel | 8·91 | 5·94 | 5·43 |
| Silica and residue | 1·41 | | |
| | 99·74 | 99·07 | 99·55 |

*Loewe's Analyses.*

| | | |
|---|---|---|
| Iron | 90·470 | 91·361 |
| Nickel | 7·321 | 7·323 |
| Cobalt, carbon, and silica | 1·404 | 0·938 |
| Sulphur | traces | traces |
| | 99·195 | 99·622 |

Specific gravity = 7·814.

## II.—METALLIC IRON FIVE TO FIFTY PER CENT., MOSTLY TEN TO TWENTY-FIVE PER CENT.

I.—Aerolite which fell at Château-Renard on the 12th of June, 1841. Analysis by Dufrénoy (Berzelius, Rapp. Ann., 1843):—

| | | |
|---|---|---|
| Nickeliferous iron* | | 9·82 |
| Mineral matter not dissolved by acids† | | 37·54 |
| Mineral matter dissolved by acid. | Silica | 18·19 |
| | Magnesia | 9·92 |
| | Protoxide of iron | 22·86 |
| | Sulphur | 0·35 |
| | Iron combined with sulphur | 0·08 |
| | Potassa | 0·02 |
| | | 98·88 |

* *The Nickeliferous Iron.*

| | |
|---|---|
| Iron | 81·31 |
| Nickel | 12·34 |
| Silica | 3·37 |
| Magnesia | 1·03 |
| Protoxide of iron | 1·71 |
| | 99·76 |

† *Mineral matter not dissolved.*

| | |
|---|---|
| Silica | 51·77 |
| Alumina | 10·22 |
| Protoxide of iron | 17·51 |
| Magnesia | 18·33 |
| Lime | 0·47 |
| Potassa | 0·68 |
| Soda | 2·30 |
| | 101·27 |

The entire aerolite may thus be regarded, mineralogically, as composed of:—

| | |
|---|---|
| Nickeliferous iron | 9·25 |
| Olivine | 51·62 |
| Insoluble mineral (feldspar and augite ?) | 38·17 |
| Iron pyrites | 0·67 |
| | 99·71 |

*Observation.*—Specific gravity = 3·56. A very ordinary kind of meteoric stone. One of the best analyses of aerolites which we possess.

J.—Aerolite which fell at Montrejeau (France), on the 9th of December, 1858. Analysis by Chancel and Moitessier ('Comptes Rendus,' 1859, and my "Foreign Correspondence" in the 'Geologist,' June, 1859):—

| | |
|---|---|
| Magnetic portion (iron and iron-oxide) | 10·04 |
| Chrome iron | 0·67 |

| | | |
|---|---|---|
| Protosulphide of iron | | 5·72 |
| Peridot (olivine) | | 45·08 |
| Oligoclase | 10·99 | |
| Augite | 26·59 | * 37·58 |
| Or, Labradorite | 8·34 | |
| Hornblende | 29·17 | 37·51 |
| | | 99·02 |

* According as the alkalies obtained in the analysis are attributed to labradorite or to oligoclase, the portion soluble in acids becomes hornblende or augite.

*Observations.*—Specific gravity = 3·30. I must refer to my paper above quoted for the discussion of this analysis and that of other chemists. The stone attracts the magnet, but has no poles. Before the blowpipes it becomes black, but does not melt. It was fused completely before the oxy-hydrogen blowpipe; the result was a black globule, not unlike the black rind of the aerolite itself. It may be stated here that although Humboldt looked upon the substance of aerolites as extremely infusible, stating that the greatest heat of our porcelain furnaces was insufficient to produce upon them the remarkable black rind, yet Laroque and Bianchi, of Toulouse, have more than once produced the *black rind,* by subjecting a portion of the interior mass of an aerolite to the flame of a common blowpipe, and have communicated those results to the 'Comptes Rendus' of the Paris Academy (1859). The structure of the aerolite of Montrejeau is granular, with numerous small brilliant laminæ of a metallic aspect. There is another analysis of this aerolite by Damour ('Comptes Rendus,' 1859); it agrees tolerably with the above. He gives for its specific gravity 3·57, and for fragments fused before the blowpipe 3·29; like many other mineral substances, it therefore diminishes in density by fusion.

K.—Aerolite which fell at Tourinnes-la-Grosse, near Louvain (Belgium), on the 7th of December, 1863. Analysis by F. Pisani ('Comptes Rendus,' Jan. 18, 1864).

| | |
|---|---|
| Metallic iron | 11·05 |
| Nickel | 1·30 |
| Tin | 0·17 |
| Sulphur | 2·21 |
| Chrome iron | 0·71 |
| Silica | 37·47 |
| Alumina | 3·65 |
| Protoxide of iron | 13·89 |
| Oxide of manganese | traces |
| Magnesia | 24·40 |
| Lime | 2·61 |
| Soda and potassa | 2·26 |
| | 99·72 |

These elements may be grouped as follows:—

| | |
|---|---|
| Iron, with nickel, tin, and traces of phosphorus | 8·67 |
| Pyrites (non-magnetic) | 6·06 |
| Chrome iron | 0·71 |
| Silicates | 84·28 |
| | 99·72 |

*Observations.*—Of these silicates, 48·90 are soluble in acid and represent *olivine;* 51·10 are not soluble and represent *augite,* probably mixed with a little feldspar. Specific gravity of the stone=3·525. The iron portion alone is attracted by the magnet, the pyrites remaining with the silicates. An excellent and very carefully made analysis, like all those leaving the laboratory of Felix Pisani. For the figures of the soluble and insoluble silicates considered separately, I must refer to the 'Comptes Rendus' (*loc. cit.*).

L.—Aerolites which fell, the one at Utrecht, on the 2nd of June, 1843, the other at Sommer County (North America), on the 22nd of May, 1827; both analysed by Baumhauer (Poggendorff, 'Annalen,' lxvi. 463).

| | 1843. | 1827. |
|---|---|---|
| Metallic iron | 11·068 | 12·806 |
| Nickel and cobalt | 1·242 | 1·657 |
| Copper and tin | 0·025 | 0·065 |
| Sulphur | 1·897 | 1·804 |
| Phosphorus | 0·005 | — |
| Protoxide of iron | 15·296 | 10·029 |
| Oxides of manganese and nickel | 0·609 | 2·310 |
| Oxide of chrome | 0·656 | 1·374 |
| Oxides of copper and tin | 0·256 | 2·528 |
| Alumina | 2·252 | 4·807 |
| Magnesia | 24·366 | 22·789 |
| Lime | 1·480 | 0·700 |
| Soda | 1·395 | 0·594 |
| Potassa | 0·152 | 0·025 |
| Silica | 39·301 | 38·508 |
| | 100·000 | 99·991 |

*Observations.*—These very elaborate analyses show that the two stones, which fell at long intervals and in distant countries, are very similar in composition; the author shows in his admirable paper that the constituents of the two meteorites may be grouped as follows:—

| *Stone of* 1843. | | *Stone of* 1827. | |
|---|---|---|---|
| Olivine | 48·013 | Olivine | 45·062 |
| Augite | 25·328 | Labradorite | 3·722 |
| Albite | 11·427 | Amphibole | 32·901 |
| Magnetic pyrites | 5·097 | Magnetic pyrites | 4·846 |
| Chrome iron | 0·941 | Chrome iron | 1·973 |
| Nickeliferous iron, with copper, tin, and phosphorus | 9·140 | Nickeliferous iron | 11·496 |
| | 100·000 | | 100·000 |

M.—Aerolite which fell at Alessandria, in Italy, on the 3rd of February, 1860. Analysis by Schrauf and Missaghi (Pogg. Ann., 1863):—

| | |
|---|---|
| Metallic iron | 19·370 |
| Nickel | 1·077 |
| Chrome | 0·845 |
| Manganese and cobalt | traces |
| Oxide of iron | 12·831 |
| Magnesia | 11·176 |
| Alumina | 8·650 |
| Lime | 3·144 |
| Sulphur | 3·831 |
| Silica | 37·403 |
| | 98·327 |

*Observations.*—There were doubtless traces of phosphorus, as usual. The stone is irregular in form, of uneven breakage, dark-coloured, smooth on the exterior surface; specific gravity = 3·815. It acts upon the magnetic needle in a remarkable manner. The specific gravity of the fused black rind was found to be = 4·864, it is therefore much more dense than the interior mass of the stone; mineral substances diminish in density by being fused, but there are some exceptions.

N.—Aerolite which fell near the village of Kleinwenden, near Nordhausen (Germany), on the 16th of September, 1843. Analysis by Rammelsberg (Berz. Rapp. Ann., 1846) :—

| | |
|---|---|
| Metallic iron | 23·90 |
| Nickel | 2·37 |
| Tin | 0·08 |
| Copper | 0·05 |
| Sulphur | 2·09 |
| Phosphorus | 0·02 |
| Oxide of chrome | 0·62 |
| Magnesia | 26·64 |
| Protoxide of iron | 6·90 |
| Alumina | 3·75 |
| Lime | 2·83 |
| Protoxide of manganese | 0·07 |
| Potassa | 0·38 |

| | |
|---|---|
| Soda | 0·28 |
| Silica | 33·03 |
| | 100·01 |

*Observations.*—One of the most perfect analyses of meteoric stones that we possess. The author shows (*loc. cit.*) that this aerolite is composed of—

| | |
|---|---|
| Nickeliferous iron | 22·904 |
| Chrome iron | 1·040 |
| Magnetic pyrites | 5·615 |
| Olivine | 38·014 |
| Labradorite | 12·732 |
| Augite | 19·704 |
| | 100·009 |

O.—Meteorite which fell at Ohaba (Transylvania), on the 10th of October, 1857. Analysis by Dr. Buckheisen (Répert. de Chim., 1859):—

| | | | | |
|---|---|---|---|---|
| Iron | 21·40 | Grouped by the author as follows: | Olivine | 44·85 |
| Nickel | 1·80 | | Pyroxene and feldspar | 18·27 |
| Sulphide of iron | 13·14 | | Nickeliferous iron | 23·76 |
| Silica | 36·60 | | Sulphide of iron | 13·14 |
| Magnesia | 23·45 | | | 100·00 |
| Protoxide of iron | 1·75 | | | |
| Protoxide of manganese | 0·15 | | | |
| Alumina | 0·28 | | | |
| Potassa and soda | 0·98 | | | |
| Chrome iron | 0·56 | | | |
| Lime and phosphorus | traces | | | |
| | 100·11 | | | |

*Observations.*—The specific gravity of this stone = 3·11. It is possessed of the usual black rind. The interior is of a light-green colour, slightly tinged with dark bluish-grey, with indistinct spherical concretions, abundance of coarse and fine particles of metallic iron, and very minute particles of magnetic sulphide of iron. The olivine is dispersed through the whole of it in scarcer grains. This meteorite is very similar to that of Château-Renard (June, 1841).

*Note.*—On *the crystalline minerals found in aerolites,* see the admirable paper by Gustav Rose (in Ann. de Chim., 1826), the original investigator of this interesting subject.

P.—Partial analyses, by M. Giraud, of two aerolites which fell in India (L'Institut, n. 822, p. 319) :—

| | I. | II. |
|---|---|---|
| Earthy silicates | 58·30 | 19·50 |
| Sulphur | 2·50 | 0·00 ? |
| Nickel | 6·76 | 4·24 |
| Iron | 22·18 | 69·16 |
| | 89·74 | 93·90 |

*Observations.*—No. I. fell on the 15th of February, 1848. Its specific gravity = 3·512. No. II. was found; when it fell is unknown; it was dug out of the ground; its sulphur may have been oxidized, and disappeared by the influence of damp, etc. Its specific gravity = 4·72 to 4·90.

The specific gravity of aerolites always increases with the amount of metallic iron present.

### III.—METALLIC IRON 3 TO 0·1 PER CENT., AND EVEN LESS.

Q.—Aerolite which fell at Kaba (Hungary), April, 1857. Analysis by Wöhler (Imp. Acad. Sc. Vienna, 1859) :—

| | |
|---|---|
| Metallic iron | 2·88 |
| Nickel | 1·37 |
| Magnetic pyrites | 3·55 |
| Silica | 34·24 |
| Magnesia | 22·39 |
| Protoxide of iron | 26·20 |

| | |
|---|---|
| Protoxide of manganese | 0·05 |
| Alumina | 5·38 |
| Potassa (and soda?) | 0·30 |
| Chrome iron | 0·89 |
| Carbon | 0·58 |
| Lime | 0·66 |
| Cobalt, phosphorus, and unknown white substance | traces |
| | 98·50 |

*Observations.*—This stone has the usual black rind. Its interior mass is greyish-black, with globular concretions; it acts energetically on the magnetic needle; it most resembles in appearance the aerolite which fell at Renalzo, in Italy.

Wöhler finds in it a certain quantity of *carbon,* together with a *hydrocarbon,* somewhat similar in appearance to wax ("unknown white substance") and probably analogous to ozokerite, scheererite, or paraffine. This hydrocarbon is extracted from aerolites by means of alcohol, in which it is soluble. The presence of carbon in meteoric stones, now several times demonstrated with certainty, is interesting on account of the immense heat the stones were subjected to in passing, as fire-ball meteors, through the air. It is true that this heat seems only to affect their surface when the *black rind* is formed by fusion of the stony mass; the black colour of this rind is *not* owing to carbon; but the *blackish* colour of the *interior* of the Kaba meteorite is owing to it.

R.—Meteorite which fell near Tulbach (Cape of Good Hope), on the 13th of October, 1838. Analysis by Mr. Harris, in Professor Wöhler's laboratory (Imp. Acad. Sc. Vienna, 1859); previously analysed by Faraday (Pogg. Ann. xlvii.) :—

| | Wöhler and Harris. | Faraday. | |
|---|---|---|---|
| Metallic iron | 2·50 | | |
| Nickel | 1·30 | Oxide of nickel. | 0·82 |
| Sulphur | 3·38 | | 4·24 |
| Silica | 30·80 | | 28·90 |
| Protoxide of iron | 29·94 | | 33·22 |
| Magnesia | 22·20 | | 19·20 |
| Lime | 1·70 | | 1·61 |
| Alumina | 2·05 | | 5·22 |
| Oxide of chrome | 0·76 | | 0·70 |
| Potassa and soda | 1·23 | Water | 6·50 |
| Oxide of maganese | 0·97 | Cobalt and soda | traces |
| Cobalt and phosphorus | traces | | |
| Copper | 0·03 | | 100·41 |
| Carbon | 1·67 | | |
| Bituminous hydrocarbon | 0·25 | | |
| | 98·78 | | |

Professor Faraday notices in it "a little metallic iron," estimated here along with the protoxide of iron.

*Observations.*—It will be observed that this and some of the previous analyses emanating from Professor Wöhler's laboratory (analyses O, P, and Q) show a very large amount of *metallic* nickel, compared with that of metallic iron; I have doubts that the whole of the nickel exists in these aerolites in the metallic state; at least one-half of the 1·30 metallic nickel must be in the state of *oxide of nickel,* and be present as such in the olivine (soluble silicate of the aerolite).

This meteorite is black, opaque, and soft, it greatly resembles that of Kaba (Hungary). Faraday observed that this stone is tender, porous, and hygroscopic, becoming moist by exposure to the air; its specific gravity is 2·94, its black colour is owing to carbon.

S.—Meteorite which fell at Uden (Brabant), on the 12th of June, 1840. Analysis by Baumhauer and Seelheim (Répert. de Chim., 1863):—

| | | |
|---|---|---|
| Portion attracted by the magnet | Magnetic pyrites . Nickeliferous iron . | 1·73 |
| Silicate soluble in acids (olivine) 55·28 per cent. | Silica | 20·71 |
| | Protoxide of iron | 18·36 |
| | Magnesia | 15·49 |
| | Protoxide of manganese | 0·43 |
| | Oxide of nickel | 0·29 |
| Silicates insoluble in acids (feldspar and augite) 40·91 per cent. | Silica | 23·87 |
| | Magnesia | 5·18 |
| | Protoxide of iron | 4·05 |
| | Lime | 2·28 |
| | Alumina | 4·10 |
| | Soda | 0·94 |
| | Potassa | 0·49 |
| | Chrome iron | 0·76 |
| | Sulphide of iron | 0·72 |
| | | 99·44 |

*Observations.*—This meteorite appeared to be at the time of its fall an *entire stone,* and not a fragment of some larger body; it weighed originally seven hundred and twenty grammes (about twenty-four ounces), and was *completely* covered by the black rind. The moment it fell it was much too hot to be touched without inflicting a burn. A very excellent analysis: perhaps we could not have a better model of an analysis than this for aerolites in general. The black crust was not included in the analysis, which, therefore, represents the composition of the interior grey mass of the stone.

T.—Aerolite which fell at Juvenas (Ardèche,) on the 18th of June, 1821. Analysis by Rammelsberg (Gilbert's Ann. der Phys. und Chemie, vol. lxxiii. p. 585):—

| | |
|---|---|
| Metallic iron | 0·16 |
| Oxide of chrome | 0·24 |
| Titanic acid | 0·10 |
| Sulphur | 0·09 |
| Phosphoric acid | 0·28 |

| | |
|---|---|
| Potassa | 0·12 |
| Soda | 0·63 |
| Magnesia | 6·44 |
| Lime | 10·23 |
| Protoxide of iron | 20·33 |
| Peroxide of iron | 1·21 |
| Alumina | 12·55 |
| Silica | 49·23 |
| | 101·61 |

*Observations.*—This is the first indication of titanic acid in meteoric stones; it will probably be found in many. The presence of this substance in feldspar, serpentines, etc., was indicated by Peschier (Ann. de Chim., 1826).

The meteorite of Juvenas, of which the above is an elaborate analysis, has been previously analysed by several other chemists. Gustav Rose showed that it contained crystallized *olivine*, *augite*, and *anorthite* (a kind of feldspar), which can be mechanically separated from it. This analysis of Rammelsberg shows, according to him, that the aerolite of Juvenas consist approximatively of—

| | |
|---|---|
| Augite | 60 00 |
| Anorthite | 36·00 |
| Chrome iron | 1·50 |
| Magnetic pyrites | 0·25 |

and perhaps traces of *titanite* and *apatite*. Although Professor Rammelsberg's analysis is the best that has been made of this stone, he appears to have calculated all the magnesia as augite, leaving nothing for *olivine*, which certainly is present in the aerolite. As is always the case with aerolites, this stone was partially soluble in acids. The other previous analyses are by G. Rose, Shepard, Laugier, and Vauquelin. It may be remarked here that Damour finds as much as 1·72 per cent. of titanic acid in the lava of Hecla.

U.—Meteorite which fell at Kakowa (Hungary), on the 19th of May, 1858. Analysis by Wöhler (Imp. Acad. Sc. Vienna, 1859):—

| | |
|---|---|
| Silicates soluble in hydrochloric acid | 56·7 |
| Silicates insoluble in " " | 43·3 |
| | 100·0 |
| Metallic iron | traces |

| *Portion soluble in acid.* | | *Portion insoluble in acid.* | |
|---|---|---|---|
| Silica | 19·5 | Silica | 50·49 |
| Magnesia | 11·2 | Magnesia | 36·84 |
| Protoxide of iron | 24·4 | Lime | 1·88 |
| Nickel | 0·2 | Alumina | 5·71 |
| Lime | 0·7 | Soda | 4·45 |
| Sulphur | traces | Potassa | 0·59 |
| | 56·0 | | 99·96 |

This is an olivine with much oxide of iron.

This portion represents 82·17 of magnesian wollastonite, and 17·00 of anorthite, according to Wöhler. But these two minerals as found in the earth are decomposed by acids.

*Portion extracted by the Magnet.*

| | |
|---|---|
| Metallic iron | 82·95 |
| Nickel | 11·41 |
| Cobalt | 1·08 |
| Phosphorus, copper, and oxide of chrome | traces |
| | 95·44 |

The entire aerolite, decomposed by hydrofluoric acid, gave—

| | |
|---|---|
| Silica | 41·96 |
| Magnesia | 27·06 |
| Protoxide of iron | 33·95 |

| | |
|---|---|
| Alumina | 2·46 |
| Lime | 0·81 |
| Protoxide of manganese | 0·39 |
| Soda | 1·92 |
| Potassa | 0·56 |
| Carbon (graphite) | 0·15 |
| Nickel | 0·20 |
| Sulphur | trace |
| | 99·46 |

*Observation.*—This is an example of a meteorite, containing upwards of ninety-nine per cent. of silicates, etc., still giving, by the aid of the magnet, metallic iron of the same composition as that of Pallas!

The *black rind* of this stone is of *extraordinary thickness* (about half an inch), and extends into the interior of the meteorite as a vein. Minute particles of metallic iron are dispersed throughout the whole stone.

V.—Aerolite which fell at Chassigny, near Langres, France, on the 3rd of October, 1815. Analysis by Damour ('Comptes Rendus,' 1862); previously analysed by Vauquelin (Ann. de Chim., 1816):—

| | *Damour.* | | *Vauquelin.* |
|---|---|---|---|
| Silica | 35·30 | Silica | 33·9 |
| Magnesia | 31·76 | Magnesia | 32·0 |
| Protoxide of iron | 26·70 | Protoxide of iron | 31·0 |
| ,, ,, manganese | 0·45 | | |
| Oxide of chrome | 0·75 | Chrome | 2·0 |
| Potassa | 0·66 | | |
| Chrome iron and pyroxene (augite) | 3·77 | | |
| | 99·39 | | 98·9 |

*Observations.*—This most remarkable stone is distinguished from most aerolites by its *pale yellow colour.* Indeed, I never saw an aerolite that exactly resembled it, though there are a few somewhat similar in the British

Museum, where there is also a fragment, weighing about one ounce, of this meteorite of Chassigny. Under a lens, we distinguish in its interior a multitude of round vitreous grains, and other grains of a black colour. The stone is possessed, as usual, of a *black rind,* which portion alone is magnetic. The specific gravity of this meteorite is 3·57. It does not appear to contain any iron or nickel in the metallic state, but to consist *almost entirely* of a ferruginous olivine, as its analysis clearly shows. Before the blowpipe it can be fused to a black magnetic scoria, similar to the rind. It is decomposed by nitric acid, leaving gelatinous silica on evaporation. The fall of this stone is described in the 'Annales de Chimie,' 1816. It has only been alluded to in a former portion of this work; here are the details:—

On the 3rd of October, 1815, at half-past eight *in the morning,* the weather being fine, with a faint easterly wind, a noise was heard for three or four leagues around the village of Chassigny. It was like the discharge of musketry and cannon, and appeared to come from a *cloud* above the north-east horizon. The cloud had no particular form, and was of a grey colour. The noise had lasted for some time, when a man, at work in a vineyard at a little distance from the village, who was looking at the cloud, heard a whistling noise, like that of a bullet in the air, and saw an opaque body fall at about four hundred yards from him; *a thick smoke rose from it.* He ran to the spot, and found a hole in the soil some two feet deep, and round about it fragments of a stone, which he picked up. They were quite warm, as if they had been much heated by lying in the sunshine. This man went and described what he had witnessed to Dr. Pistollet, who wrote the account in the

'Annales de Chimie,' 1816. *No globe of fire* was seen in this case; and the *cloud* discharged nothing during the detonations. No doubt the latter was left behind by the meteor itself. A number of fragments of this aerolite were picked up. The entire stone must have weighed about eighteen pounds English.

W.—Meteoric stones which fell near Alais, Gard (France), on the 15th of March, 1806. Analysis by Thenard ('Annales de Chimie,' lxi. p. 103) :—

| | |
|---|---|
| Silica | 21·0 |
| Manganese | 9·0 |
| Oxide of iron | 40·0 |
| Nickel | 2·5 |
| Magnesia | 2·0 |
| Chrome | 1·0 |
| Sulphur | 3·5 |
| Carbon | 2·5 |
| | 81·5 |

*Observations.*—An old and imperfect analysis. This aerolite is remarkable by being the first in which *carbon* was discovered. It was also examined by Berzelius in 1834, who discovered in it an *organic substance*, turning brown when heated; and on being dissolved the stone deposited a black carbonaceous substance, which burnt without residue. Professor Roscoe, of Manchester, again examined this stone in 1863, and finds that it contains 0·5 per cent. of a hydrocarbon, which is soluble in ether, from which solution it is deposited in crystals. It is a substance somewhat similar to naphthaline. There is also as much as one per cent. of *free* sulphur in this aerolite.

The specific gravity of the Alais meteorite is only 1·94, it is therefore the lightest aerolite that has yet been met with. In appearance it is black, not unlike coal.

X.—Aerolites which fell at L'Aigle, in Normandy, 1823; two old and imperfect analyses, one by Thenard, the other supposed to be by Vauquelin. I am not aware that any modern analysis of these stones has been made.

| | *Thenard.* | *Vauquelin?* |
|---|---|---|
| Silica | 46 | 53 |
| Protoxide of iron | 45 | 32 |
| Magnesia | 10 | 9 |
| Nickel | 2 | 3 |
| Sulphur | 5 | 2 |
| Lime | — | 1 |
| | 108 | 107 |

The numerous stones which fell at L'Aigle were very friable for some days after their descent. This is not uncommonly the case with aerolites abounding in silicates. Laugier afterwards found chrome in one of these stones.

Y.—Aerolite which fell at Orgueil, France, on the 14th of May of the year 1864. Analyses by F. Pisani and Cloez ('Comptes Rendus' of 4th and 8th of July, 1864):—

| | *Cloez.* | | *Pisani.* |
|---|---|---|---|
| Hygroscopic water | 5·957 | | |
| Ammonia | 0·098 | (Substance dried at 110° Centigrade.) | |
| Humus | 6·027 | | |
| Combined water | 7·345 | | |
| Sulphur | 4·369 | Sulphur | 5·75 |
| Chlorine | 0·073 | Chlorine | 0·08 |
| Phosphorus | traces | Hyposulphurous acid | 0·53 |
| Sulphuric acid | 2·195 | Sulphuric acid | 1·54 |
| Silica | 24·475 | Silica | 26·08 |
| Alumina | 1·175 | Alumina | 0·90 |
| Oxide of chrome | 0·225 | Chrome iron | 0·49 |
| Peroxide of iron | 13·324 | Peroxide of iron | 8·30 |
| Protoxide of iron | 17·924 | Protoxide of iron | 21·60 |

| | | | |
|---|---|---|---|
| Oxide of nickel . . | 2·450 } | Oxides of nickel and cobalt | 2·26 |
| Oxide of cobalt . . | 0·085 } | | |
| Oxide of manganese . | 1·815 | Oxide of manganese . . | 0·36 |
| Magnesia . . . . | 8·163 | Magnesia . . . . . . | 17·00 |
| Lime . . . . . . . | 2·183 | Lime . . . . . . . . | 1·85 |
| Soda . . . . . . . | 1·244 | Soda . . . . . . . . | 2·26 |
| Potassa . . . . . | 0·307 | Potassa . . . . . . . | 0·19 |
| | 99·434 | | 89·19 |

*Cloez groups his results thus:—*

| | |
|---|---|
| Magnetic oxide of iron | 20·627 |
| Magnetic sulphide of iron . . . . . | 7·974 |
| Sulphide of nickel . | 3·169 |
| Silicates . . . . . | 45·127 |
| Humus . . . . . | 6·410 |
| Combined water . . | 7·812 |
| | 91·119 |

*Pisani calculates his Analysis as follows:—**

| | |
|---|---|
| Magnetic oxide of iron . | 12·03 |
| Nickeliferous sulphide of iron . . . . . . . | 16·97 |
| Chrome iron . . . . . | 0·49 |
| Silicates . . . . . . . | 55·60 |
| Water and organic matter | 14·91 |
| | 100·00 |

*Observations.*—This is certainly one of the most remarkable stones that ever fell. In appearance it is not unlike some kinds of lignite; the fragments are of a dark colour, and have magnetic pyrites disseminated throughout the mass; every particle of the stone is powerfully attracted by the magnet. Several stones fell, they are all exceedingly porous, and have a very low specific gravity = 2·50; alcohol dissolves from them a little free sulphur, and perhaps a little hydrocarbon. Their dark colour is owing to the carbonaceous matter they contain, and which causes them to leave streaks on paper. A very small quantity of *carbonate of manganese* has been recently discovered in these stones. According to Cloez, the carbonaceous matter they contain has nearly the composition of peat, as will be seen on comparing the composition of these two substances.

* The figures are given from a corrected paper forwarded to me by M. Pisani, the note in 'Comptes Rendus' having several misprints.

| *Organic matter of the Aerolite.* | | *Average composition of Peat.* | |
|---|---|---|---|
| Carbon | 63·45 | Carbon | 60·06 |
| Hydrogen | 5·98 | Hydrogen | 6·21 |
| Oxygen | 30·57 | Oxygen | 33·73 |
| | 100·00 | | 100·00 |

It is the first time that this kind of substance has been met with in a meteoric stone. Pisani assures us that the nickel exists in the aerolite of Orgueil as sulphide of nickel, for it is dissolved from the stone by sulphide of ammonium. The small quantity of hyposulphites present is doubtless the result of a decomposition of the sulphides, for the stones are very porous. After drying, this aerolite, like that of the Cape, is remarkably hygroscopic, and attracts seven per cent. of moisture in a very short time.

Pisani finds that this interesting aerolite contains 3·35 per cent. of salts soluble in water, which are chlorides, sulphates, and hyposulphites of magnesia, lime, soda, potassa, and ammonia. Alcohol dissolves 0·37 per cent. of the stone, the portion thus extracted consisting principally of sulphur, but containing, doubtless, a small amount of some hydrocarbon like naphthaline, etc. All things well considered, this aerolite appears to differ a little from any other that has yet been analysed, principally by the fact that so large a proportion of magnetic oxide of iron precludes the existence of olivine; but, as Pisani remarks, if the magnetic oxide is calculated, in his analysis, as *protoxide, then we have exactly the proportions of an olivine.* In my own mind there is no doubt that the stone began to decompose rapidly as soon as it fell to the earth, and the little iron that it may have contained in the metallic state has been rapidly oxidized.

As this is the last aerolite which has been seen to fall, I may be excused for discussing somewhat at length its chemical composition. The presence of so large an amount of humus or peaty substance is certainly very remarkable, and connects this aerolite with that of Alais and that of the Cape.

We have now come to the end of our alphabet of analysis; one more letter (Z) remains, and this I will devote to the composition of one or two volcanic products, merely as a sort of comparison, and without many remarks at present.

## IV.—APPENDIX TO COMPOSITION OF AEROLITES.

Z.—Analyses of certain volcanic products.

*a.* Rapilli of the Köhlerberg, Silesia. Analysis by Zulkowsky (Répert. de Chim., 1859) :—

| | |
|---|---|
| Water | 2·005 |
| Peroxide of iron | 15·095 |
| Alumina | 12·665 |
| Oxide of nickel | 0·109 |
| Magnesia | 16·316 |
| Lime | 4·799 |
| Silica | 48·280 |
| Traces of phosphoric acid, cobalt, potassa, and loss | 0·731 |
| | 100·000 |

*Observations.*—The Köhlerberg mountain, near Freudenthal, in Silesia, is almost entirely formed of *lava, volcanic bombs,* and layers of *rapilli* (or *lapilli,* porous volcanic stones) which give the above composition.

*b.* Ash or cinder of Etna, eruption of 1822. Analysis by Vauquelin (Ann. de Chim., 1826) :—

| | |
|---|---|
| Silica | 28·10 |
| Sulphide of iron | 20·88 |
| Sulphate of lime | 18·00 |
| Alumina | 8·00 |

| | |
|---|---|
| Lime | 2·60 |
| Carbon | 1·00 |
| Copper and sulphur | traces |
| Alkalies and moisture | 21·42 |
| | 100·00 |

*c.* Ash or cinder of Vesuvius, eruption of February, 1850, qualitatively examined by H. Rose (Millon, Annuaire, 1851) and Ehrenberg (*id.*) :—

Black powder, attracted by a magnet, contains silica, protoxide of iron, magnesia, alumina, lime, peroxide of iron, and a little phosphoric acid.

Ehrenberg examined the ash microscopically, and finds that it contains a certain amount of organic matter, which he supposes to be *débris* of vegetables. Under the microscope the ash appears formed of irregular grains, showing no crystallization, but some possessed of double refraction, and therefore crystalline.

*d.* Lava of Hecla, eruption 1852 (Van Hauer), and *idem*, eruption of 1669 (Abich); their analyses lead to the following result:—

| *Lava of* 1852. | | *Lava of* 1669. | |
|---|---|---|---|
| Labradorite and augite | 95 | Labradorite | 54·80 |
| Olivine | 2 | Augite | 34·14 |
| Magnetic oxide of iron | 3 | Olivine | 7·98 |
| | | Magnetic oxide of iron | 3·08 |
| | 100 | | 100·00 |

I now terminate this chapter with the following remark, namely, that *the only products upon our earth which at all resemble meteoric stones in their chemical composition are the products of volcanoes.* We shall see in the sequel whether this fact may, or may not, be utilized in the discussion of the origin of these remarkable meteoric phenomena.

# CHAPTER XII.

## ATTEMPTS TO FORM AEROLITES ARTIFICIALLY; AND ON THE MICROSCOPIC STRUCTURE OF METEORIC STONES.

After making ourselves thoroughly acquainted with the composition of a mineral substance, it is interesting to inquire whether it is not possible to form it artificially in the laboratory; such an experiment often leading to an exact explanation of its formation in nature. These attempts, in the hands of Ebelman, De Senarmont, Daubrée, and others, have met with great success, and the artificial formation of wollastonite, feldspar, and several other crystallized minerals, have clearly shown that superheated steam, or water heated under great pressure, has been evidently active in their formation by nature.*

Nothing resembling in the least a meteoric stone, or aerolite, has however yet been formed. I am not aware that the attempt has been made by others, but all my endeavours have hitherto failed to produce a substance having the appearance and structure either of earthy meteorites or of meteoric iron.

* See, more especially, Daubrée's interesting papers in the 'Annales des Mines,' and the 'Comptes Rendus,' 1857–1859.

M. Faye has lately been more successful in the artificial formation of schreibersite—a substance which we have seen to be peculiar to aerolites, and the only compound in them which we cannot connect with any known mineral found in the rocks or strata of the earth.

Schreibersite, we said, is a phosphide of iron and nickel, which presents itself in bright metallic laminæ, generally very small, and of a yellowish colour, not unlike some kinds of common iron pyrites, for which it has been frequently mistaken. It always shows the same chemical composition, that is, the same amount of phosphorus, iron, and nickel,—containing two proportions of nickel, four of iron, and one of phosphorus ($Ni_2Fe_4Ph$). But its two distinctive characters are, first, that it is highly magnetic; second, that it is not dissolved in either cold or hot hydrochloric acid.

This substance is not only peculiar to aerolites, but it contains all their phosphorus. When it has been mechanically separated from a meteoric stone, the remainder shows no trace of phosphorus. It exists alike in stony aerolites and in meteoric irons.

It was therefore an interesting attempt to endeavour to form this substance artificially, and this has been done in the most satisfactory manner by M. Faye, the well-known astronomer, in the laboratory of M. H. Deville, of Paris. The experiment consisted in smelting at a very high temperature, a mixture of oxide of iron, oxide of nickel, phosphate of soda, etc., in a plumbago crucible. The proportions of the different substances which it was considered proper to take were as follows:—Peroxide of iron 8 grammes, oxide of nickel 3·7, pyrophosphate of soda 10·1, silica 6, carbon 2. This mixture was placed in a plumbago crucible (or in a crucible made of the charcoal of gas-works), protected by an earthen crucible, and submitted for some time to a white heat. The result was a black glass containing a metallic button, the latter surrounded by a very distinct crust which adhered to it.

The metallic button consisted of iron and nickel, and was easily attacked by hydrochloric acid; the crust was not attacked by acid, but was seen to be composed of yellow laminæ, with a metallic aspect, eagerly attracted by the magnet, and quite insoluble in hot or cold hydrochloric acid. This artificially-formed substance possesses, therefore, all the characters of schreibersite, with which it is no doubt identical; it remains only to submit it to analysis, in order to certify that its composition is similar to that of the meteoric mineral.*

This is also the place to mention some results lately obtained by Mr. H. C. Sorby, in examining the microscopic structure of aerolites. The author formerly published in the 'Quarterly Journal of the Geological Society' (1858, vol. xiv.) some investigations into the microscopic structure of crystals. He has since examined microscopically several meteoric stones, and finds, in the first place, that the olivine of aerolites, like that of the volcanic rocks, contains occasionally very minute cavities, which the author calls "glass cavities," and thinks they evidently indicate that the substance in question was at one time in a state of igneous fusion. The olivine of aerolites also contains "gas cavities" like those which are so common in volcanic minerals, indicating the presence of some gas or vapour. The so-called "glass cavities" contain a sort of brown or

* See *Appendix*, for a note upon the recent interesting experiments of Professor Daubrée.

brownish-red vitreous substance, which is also found outside some of the grains. A very strong magnifier is necessary to detect these cavities. Mr. Sorby also affirms that some isolated portions of meteorites have a microscopic structure very similar to that of stony lava, whilst others possess a structure remarkably like that of consolidated volcanic ashes,—so much so indeed, that some specimens of the latter might readily be mistaken at first sight for fragments of aerolites.

When hydrochloric acid is poured on meteoric irons, and, after being allowed to remain for a little time, is wiped off with a cloth, and the surface washed, those curious lines and streaks, known as "Widmannstäten figures," appear, to which I have already alluded in Chapter XI.

# CHAPTER XIII.

## ON METEORIC DUST, AND OTHER MATTERS OBSERVED TO FALL FROM THE ATMOSPHERE.

We have seen in former chapters that meteoric stones are often very friable for some time after their fall, and are easily reduced to powder; that others are very tender and porous, and likewise fall easily to powder; and again, that some aerolites were found, on being picked up, to be accompanied by a small quantity of dark powder. Other meteorites are, on the contrary, very hard, and much more difficult to break. But we possess numerous observations which appear to prove most distinctly that some fire-ball meteors when they explode throw down nothing but meteoric dust; they present all the phenomena we have attributed to these meteors, detonations, vivid light, etc., and sometimes one or more stones appear to have been precipitated with the dust.

It is also known that volcanic ashes are often carried to a great distance and precipitated over large tracts of country, and the different accounts that have been published concerning the fall of dust, red or black rain or snow, etc., render it extremely difficult to distinguish with certainty the production of volcanic dust from that which is produced by meteors, especially where these accounts are somewhat vague, which is most frequently the case. Not only is it affirmed that meteors, on exploding, have shot down black or reddish dust at various periods, but also a peculiar substance more or less resembling charred paper, and even certain gelatinous substances.

In this chapter I intend to bring forward a few cases of meteoric dust, etc., which were evidently the results of explosions of fire-ball meteors, and to distinguish them from certain other phenomena of quite a different character.

The earliest of these falls of *black dust* appears, according to Chladni, to have happened in the year 475, on the 5th or 6th of November, in the neighbourhood of Constantinople. The old accounts say "the heavens appeared to be on fire," which would indicate a meteor, whilst other writers attribute the phenomenon to Vesuvius, in which case it would be similar to the luminous dust of this volcano noticed in my work on 'Phosphorescence,' etc., p. 46.

It is well known at the present day that red patches on the ground in damp country places are owing to the development of *Palmella sanguinea*, a microscopic plant of great beauty; that red-coloured snow in the Alps and elsewhere is owing to the rapid growth of *Protococcus nivalis*, another minute cryptogam, and not only that red and black rains have been undoubtedly produced by the presence of volcanic ashes in the air, but that fragments of rock, mineral ores, and hay, are sometimes transported to a great distance by water-spouts, and finally precipitated to the earth in far-off localities; moreover, that the Red Sea, and some of the saltmarshes in the south of France, sometimes contain patches of organized beings invisible to the naked eye, but which communicate a remarkable colour to the water. These facts must be borne in mind when perusing some of the older accounts of falls of meteoric dust, red rain, etc., especially when it is asserted that the ground or the snow, or the water of a lake, appeared red after the passage of a fire-ball meteor.

In the 'Manuscript of Solomon,' senator of Bremen, it is recorded that on the 3rd of December, 1586, there fell at Verde, in Hanover, a quantity of a red and blackish substance, accompanied by detonations and a vivid light, described as lightning and thunder, and that the substance charred certain planks on which it fell.

Again on the 31st of January, 1686, there fell from the air, near Rauden, in Courland, and at the same time in Norway and in Pomerania, a considerable quantity of a membranous substance, friable, and blackish, not unlike *charred paper*. It was examined by the celebrated Theodore von Grotthus, who analysed a portion of this substance which had been kept in a cabinet of natural history, and found in it *silica, iron, lime, carbon,* and *magnesia,* with traces of *chrome* and *sulphur*, but no nickel.

In 1791 there was a fall of sand in the Atlantic Ocean, accompanied by a luminous meteor (north lat. 45°, long. 322°). The fact is registered in the 'Mémoires de l'Académie des Sciences,' but the sand was not examined.

Chladni indicates a considerable number of similar cases in his catalogue (Ann. de Chim., 1826), but their meteoric origin is for the most part extremely doubtful.

The 'Penny Cyclopædia' informs us that on the 15th of November, 1755, rain of a red colour fell around Lake Constance and Ulm, and on the same day in Russia and Sweden. The water of the lake, coloured red, was acid to the taste, probably from the presence of sulphuric acid, and it deposited a flaky precipitate, like snow, *which was attracted by the magnet.*

After the destruction of a meteor near Paz, in Peru, there was a fall of a substance like cinders, which lasted continuously during the 27th, 28th, and 29th of August, 1792 (Chladni).

The 'Bibliothèque Britannique' (1813 and 1814)* tells us that on the 13th and 14th of March, 1813, there fell in Calabria, Tuscany, and Friuli, a great quantity of *red dust,* which appears to have coloured the snow then upon the ground. The phenomenon was accompanied by much noise, and continued for many hours; the noise and red dust were observed at Arezzo, and also described by Fabroni (in the Ann. de Chim., lxxxiii.). Meteoric stones fell at the same time at Cutro, in Calabria. The noise is compared to the dashing of waves at a distance, and the greatest fall was accompanied by two or three explosions like thunder. The chemist Sementini examined the dust, and found it contained *silica,* 33·0, *alumina* 15·5, *lime* 11·5, *oxide of iron* 14·5, *oxide of chrome* 1·0, *carbon* 9·0, loss in analysis 15·3. It appears that Sementini did not seek for *magnesia* or *nickel;* the former would perhaps occupy much of the fifteen per cent. loss; some of this loss is in the author's paper ascribed to a yellow organic substance soluble in alcohol.

It is easy to conceive that after the explosion of a large meteor, a quantity of red or black meteoric dust

* Also 'Blackwood's Edinburgh Magazine,' 1818.

may remain suspended in the air, and be afterwards brought down to the earth by showers of rain or snow. This may explain some cases of coloured rain, but certainly not all.

In 1819, according to Chladni's Catalogue, there fell in the month of November, at Montreal, Canada, and in the Northern States, black rain and snow that appears to have been accompanied by a meteor which exploded.

Dr. Zimmermann, of Giessen, examined the sediment left by a red rain which fell at nine o'clock in the morning on the 3rd of May, 1831, in the neighbourhood of that town. It was a reddish-brown sediment, and he found it contained *silica, oxide of iron, lime, carbon, chrome*, a trace of *magnesia* and some *volatile substances*, but no nickel.

It will be easily seen that the aerolites which most resemble these meteoric dusts and fragments, are those of Alais, Kaba, the Cape, and the curious stones which fell in 1864, near Orgueil. All these are porous and friable, and all contain carbon and carbonaceous matter, which gives to them a dark colour.

It is interesting to note that those meteoric dusts which happen to have been examined hitherto, all contain *carbon*, like the aerolites we have just named.

It is exceedingly probable, judging from the few data we possess, that some meteors on exploding throw down *nothing but dust*, and this may explain why no stones are afterwards to be found, although they may have been diligently sought for over many square miles. The 'Buenos Ayres Gazette' of the 1st of November, 1824, informs us that on the 13th of August of that year, *dust* fell from a black cloud. "When at a distance of forty leagues the same cloud discharged itself again."

Baron von Reichenbach, a man who has distinguished himself by his zeal for scientific research, and to whom we owe several interesting chemical discoveries, though his theories are often very vague and far-fetched, believes that the dust produced by evèry shooting-star gradually finds its way to the surface of the earth, and as the number of falling stars observed in a single year is very considerable, this dust may be sought for on exposed plateaux, on the elevated sides of mountains, etc. Reichenbach has collected, with these views, a quantity of samples of earth taken from the surface of high plains and desert places, and on submitting them to analysis thinks he has in every case detected the presence of nickel and cobalt. (See the journal 'Cosmos,' 29th of December, 1864; see also Chapter XVII. of this volume.)

Ships sailing at a great distance from the coast of Africa have been sometimes observed to be suddenly covered with dust, which, in spite of their enormous distance from land, is generally supposed to have been carried by the wind from the distant shores. Here are two instances which have been noted by François Arago in the 'Annuaire du Bureau des Longitudes':—

On the 19th of January, 1825, during the night, the English ship 'Clyde,' sailing northward and being opposite to that portion of the coast of Africa comprised between the river Gambia and the Cape Verde, but at a distance from this coast extending six hundred miles, it was observed on the following morning that all the sails, masts, and in fact the entire equipage, was covered with a very fine sand of a brown colour. The wind had been high during the night, *blowing between N.E. and E.*

A very similar phenomenon occurred to the eminent Russian navigator Schabelski, when his ship was in 23° north latitude and 21° 20′ longitude west of Greenwich. "The crew observed," he says, "a very remarkable phenomenon. On the morning of the 22nd of January, 1822, when we were at a distance of two hundred and seventy-five nautical miles from the coast of Africa, we perceived that all the rigging of the ship was covered with a pulverulent substance of a reddish colour, like ochre. It was very soft to the hand, and coloured the skin red. Examined under the microscope, the ropes of the rigging appeared covered with long files of globules which appeared to be in contact. It was only those portions of the rigging exposed to the *north-east wind* that were thus covered with dust."

These are examples of dust from the land carried hundreds of miles by the trade winds; there are many such ou record, and they must not be confounded with well-ascertained cases of meteoric dust, the products of meteors or falling stars.

In conclusion of this chapter, we may observe, that true meteoric dust, whatever its colour, generally contains grains of augite, or its particles are attracted by the magnet, or it gives, on being analysed, indications of nickel, chrome, carbon, etc., as well as iron and silica. The dust carried far out to sea by the trade winds is mostly *siliceous*; whilst black volcanic dust, which sometimes has travelled to the north of Scotland where it has fallen with the rain, may be often difficult to distinguish from the dust left in the air by meteors or falling stars.

The so-called "meteoric mucilage" which at certain periods appears near ponds of stagnant water in northern Europe, especially north Germany, Belgium, etc., which is said to be sometimes phosphorescent, and is generally supposed by the peasants (probably from the circumstance of its being luminous at night) to have been thrown from falling stars, has been shown to be nothing but frog-spawn, voided by the large crows of these districts.*

Again, black stones, not unlike fragments of aerolites, are sometimes carried through the air by waterspouts, and deposited over towns during a storm; such was the case with those stones of which I published an analysis in 1864 (British Association Report, 1864); they had been transported from the neighbourhood of Dudley to the town of Birmingham. Berzelius has noticed a similar transportation of grains of ironstone ('Jahresbericht'), and recently Daubrée has brought forward similar examples ('Comptes Rendus,' 1864). In June, 1861, I observed the air over Putney filled with pieces of hay, carried to an immense height and falling over Putney, Fulham, etc., the weather being very fine and perfectly calm ('Comptes Rendus,' 1861).

* *Vide* Phipson, "Sur une Espèce particulière de Mucilage Animale" (Journ. de Pharmacol. et de Med., Bruxelles, 1855).

# CHAPTER XIV.

## BOLIDES AND SHOOTING STARS.

The word *meteor*, which has been so extensively used to designate those brilliant phenomena described in some of the foregoing chapters, is unfortunately applied also to rain, hail, snow, lightning, Will-o'-the-wisp, the aurora borealis, the light of St. Elmo,—in fact, to all the phenomena treated of in the science of meteorology.* It would therefore be preferable to restrict ourselves to the word *bolide* to designate fire-ball meteors such as we have described in this work, and to distinguish these phenomena into, first, *silent bolides*, which pass through the atmosphere without exploding; and second, *exploding bolides*, which detonate and throw down stones known as aerolites. There is no longer any doubt in the scientific world that these two phenomena are essentially one and the same, as we have already stated in our first chapter; a simple, non-exploding bolide being merely a milder form of the more terrible phenomenon. Simple bolides, though frequently very brilliant and casting powerful shadows of objects on the earth's surface, are

* Many of these extraordinary developments of *terrestrial light* have been more or less fully treated of in my work on 'Phosphorescence.'

*smaller* meteors, passing much *higher* above the earth, and if they explode, doing so far below the horizon of the observer in some distant land; in other cases consuming themselves completely in their passage through our atmosphere, disappearing before they reach the horizon, and *followed by no noise*. These *silent bolides* may vary considerably in size or apparent diameter, and cast more or less light around during their passage; they may appear little larger than an ordinary shooting star, or with the dimensions of an enormous fire-ball. It is certain that they frequently do explode, though followed by no detonating rumbling or sound of any kind, and in such circumstances doubtless throw down

Fig. 9.

Explosion of a meteor, on the evening of the 7th of January, 1856, as seen over the Medina, Isle of Wight, (from a drawing by Mr. John Smith, in the 'Illustrated London News'). The same meteor was afterwards seen to take the forms shown in Fig. 11.

aerolites or meteoric dust, but at a very great distance from the observer. Thus it not unfrequently happens that their head or nucleus appears to divide into two or more distinct portions, and sometimes is seen to break up entirely whilst still many degrees above the horizon.

The smallest bolide of this kind ever witnessed was certainly that seen by myself on the 8th of December, 1863, at half-past eight in the evening. It appeared like a small shooting star in the northern sky, at an elevation of about 60° above the horizon; it shot down to about 30°, when, to my surprise, the head or nucleus suddenly burst into two or three separate fragments,

Fig. 10.

Explosion of an ordinary shooting star, as witnessed by the author, 8th December, 1863, at half-past eight in the evening.

which immediately took a dingy *red colour*, contrasting with the vivid white of the bolide an instant before. The whole phenomenon lasted scarcely more than two seconds, when everything disappeared, and no noise whatever followed within fifteen minutes of the occurrence. Indeed this bolide, had it not silently exploded in the manner described, would have been looked upon as an ordinary shooting star, scarcely illuminating even the region of the sky in which it appeared. I have since learnt that similar occurrences of very small, silently exploding bolides, have been witnessed by M. Coulvier-

Gravier and other observers, but, as it appears, not very frequently. I attach some importance to such observations, as they tend immediately to connect the phenomenon of *shooting stars* with that of the more alarming fire-ball meteors which explode and throw down aerolites.

But the most remarkable observation of this kind which we possess is certainly that made by Dr. Schmidt, Director of the Observatory of Athens, and described soon after in the journal 'Cosmos.' It was at fifty-five minutes past two in the morning of the 19th of October, 1863, that Dr. Schmidt was occupied in observing shooting stars, when he happened to see one at its very commencement, and to follow it through its entire course, availing himself at the same time of a telescope that was close at hand. This is the first *telescopic observation* of a shooting star ever made, and possesses therefore unusual interest. The following facts were noted:—At first it appeared like a star of the fourth magnitude; after two seconds of time it was of the second magnitude; at the third and fourth second, it surpassed the splendour of Sirius—the brightest star in the heavens. It slowly passed towards the west, appearing as a dazzling meteor (bolide) of 10′ to 15′ diameter. At this moment Dr. Schmidt followed the bolide in the field of a comet-seeker telescope magnifying eight diameters, and kept it in the telescope for no less than fourteen seconds, during which time it described an arc of 80°. Its appearance was most remarkable. The head or nucleus was formed of two brilliant bodies of a yellowish-green colour, in the form of elongated drops, each followed by a well-defined tail of a reddish colour. These were followed by smaller luminous bodies of the same shape, each leaving behind a red trace. The bolide disappeared at an elevation of 1° above the horizon. Four minutes afterwards Dr. Schmidt still observed the remains of the meteoric train of a yellowish-white, and covering an area of nearly 5°. At its brightest period the light of this bolide extinguished that of the stars, and illuminated the whole town of Athens, the country around, and the sea; all appeared bathed in a greenish-yellow light. No noise whatever was heard during the apparition, or after the disappearance of the bolide. Its real diameter was calculated to be about fifty-five feet, and its distance from the observer to be about sixty miles.

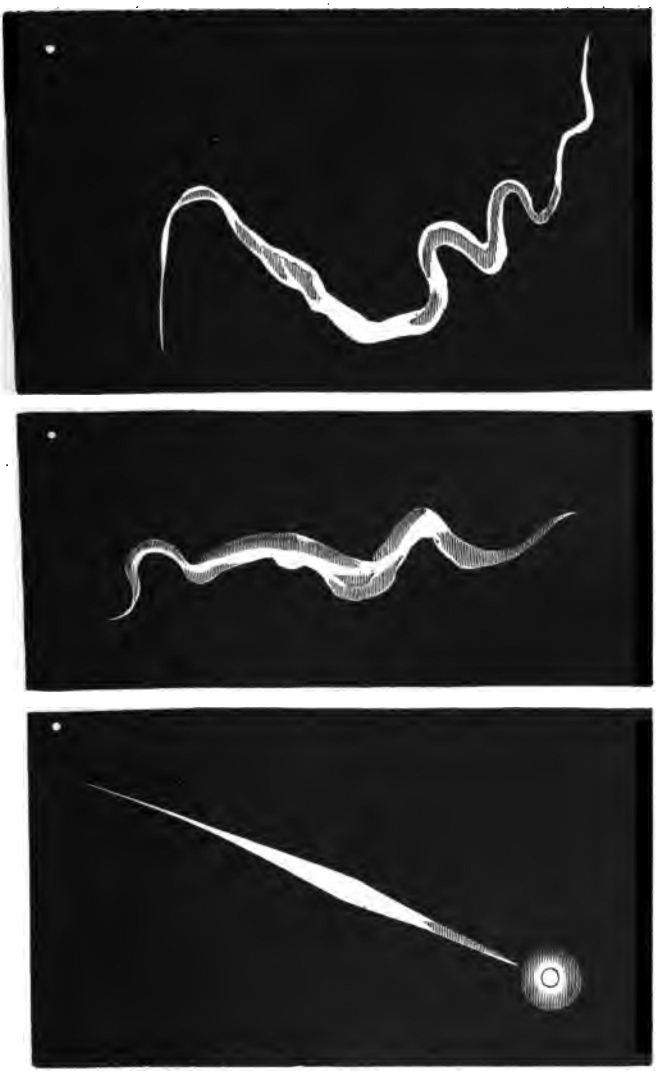
In the larger kinds of bolides a multiplicity of heads, such as observed by Dr. Schmidt, are sometimes seen by the naked eye. The bolide observed at London, on the 18th of August, 1783, had eleven, according to a drawing by Cavallo;* in some cases even more have been counted, but generally these secondary heads follow the principal body of light so closely that they give to the bolide an elongated appearance, which has been sometimes compared to a child's kite, a fish, a skittle, etc. In rare cases the bolide appears divided or double-headed.

"The ordinary forms," says Mr. Alexander Herschel, "are kite-shaped, pear-shaped, or globular."

A permanent streak often remains upon the track of a bolide; it either fades away quickly after the disappearance of the meteor, or continues visible for many minutes. In the latter case it does not always remain straight, but sometimes changes its shape and position very evidently, like a cloud moved by the wind.

In August, 1859, M. Lafollye, of Tours, transmitted to the journal 'Cosmos' an observation very

* See Chapter IV. of this work.



Forty-seven minutes past four P.M.

Fifty minutes past four P.M.

Three minutes past five P.M.

Fig. 11.

The meteor of 7th of January, 1856, as seen from Tunbridge Wells; from a drawing in the 'Illustrated London News.'

similar to that I have above described as having been made by myself on the 8th of December, 1863,—namely, the explosion of a very small bolide, little larger than an ordinary shooting-star. It was about half-past nine in the evening that the author observed a very brilliant shooting-star pass rather slowly from the constellation Cygnus to that of Cassiopeia, where it vanished. It appeared like a rocket at a very great height in the air. It left behind it a long streak, composed of brilliant points of a golden colour. Its passage might have lasted about three seconds. At about two-thirds of its course it divided itself into several fragments, the most important of which remained behind in the track of the bolide.

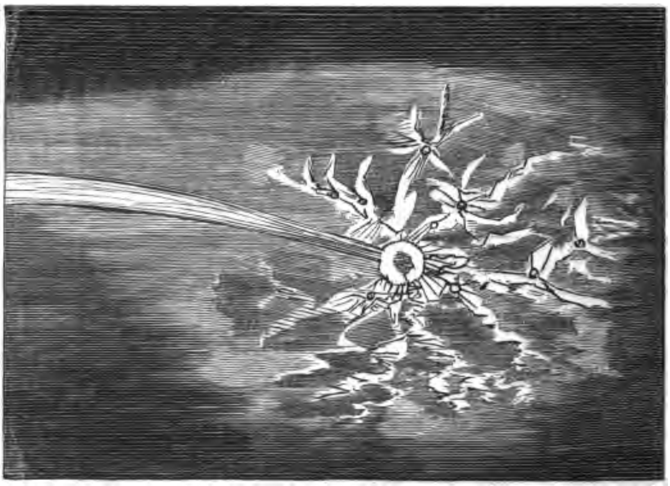


Fig. 12.

Explosion of the meteor of 11th of February, 1850, over Paddington Green; from a drawing by the late Mr. Wyatt, of London.

Some other cases of larger silently-exploding bolides have been mentioned in Chapter IX. of the present work.

On the 11th of February, 1850, the late Mr. Wyatt, of London, saw a very brilliant bolide pass over Paddington Green at twelve minutes to eleven o'clock in the evening. The appearance struck him as being so extraordinary that he published a lithographic print of the phenomenon, from a drawing taken a few minutes after the occurrence. I have seen this print, which is already very rare. It presents an ordinary globular bolide, followed by a long train of light; the head of the meteor is seen emitting a considerable number of scintillating radiations. It would be well if all who have the good fortune to witness similar phenomena, would make such a sketch as soon after the occurrence as possible.

One of the most brilliant bolides witnessed in England in recent times, was that seen by two gentlemen at Hurworth, in October, 1854. They were returning home about nine o'clock in the evening; the sky was pure and starlit, but very dark. They were noticing a constellation, when a magnificent fire-ball appeared in that region of the heavens; its apparent diameter was at least double that of the moon near the horizon; its colour was blood-red, and it shot out innumerable radiations. It left a long track of light of a golden colour. The direction of the bolide was from north-east to south-west, and its track very extensive. When its head disappeared beneath the south-west horizon, the train of light it had left in its passage was still brilliant in the north-east as when it first appeared. When the globe came just overhead, it appeared to stand still for an instant and exhibited such rapid vibrations that it was feared it would fall upon the observers themselves. At this time it was easy to perceive that the bolide had a *rapid movement of rotation, that it turned rapidly on its axis* during the whole time it was visible.

This curious vibratory motion has been often observed in bolides; I have already alluded to in a former chapter; it does not appear, however, to be generally noted. (See end of Chapter XXI.)

The size of the nucleus or head of bolides has been oftentimes overrated, on account of the intense light they emit, and which naturally causes them to appear much larger than they really are. Thus we have already seen that Halley and some of the other observers attributed to bolides they observed real diameters of about half a mile.* But modern observers seem to have been deceived by the same illusion. The *real diameter* of the meteor of Orgueil (1864) has been estimated at four hundred to five hundred metres. That of La Roy's meteor (1771), at three hundred and seventy yards; that of the Alais fire-ball (1807), at two hundred yards. Dr. Schmidt's bolide (October, 1863,) was calculated to have a real diameter of about fifty-five metres, independently of the circle of radiating light.

On the 16th of March, 1853, a bolide was seen in Holland, Belgium, Germany, England, and France; it was well observed by Dr. Heis, of the Munster Observatory, who supposes the head to have had a *real diameter* of four hundred and twenty metres,—admitting, however, at the same time, "that it must have been principally gaseous, having only a *small nucleus*."

This splendid meteor appeared in the sky about seven o'clock in the evening, in the form of an ordinary shooting star; but it gradually augmented in size until it

* See Chapter IV. of the present work.

had attained an *apparent diameter* equal to about one-fourth that of the moon, whilst its brightness increased so much that it quite extinguished the light of the stars, rendering them invisible, and brightly illuminating the surrounding landscape. It lasted about five seconds, and disappeared by exploding, the explosion being followed by a detonation.

The path of this bolide was from north to south, inclined about 22° on the horizon; it exploded fifteen or sixteen miles above the earth; it ran one hundred and seventy-one miles in five seconds, its velocity was therefore about thirty-four miles per second, which is about the ordinary velocity of the larger kinds of bolides.

The path of the Orgueil meteor, so ingeniously made out in France, shortly after the occurrence (1864), gave a velocity of only fifteen miles per second; the bolide was about thirty miles high at its commencement, and fifteen to twenty miles above the earth at the moment it exploded.

In some rare cases bolides have been said to move much slower, even as slow as three miles per second; but the *average velocity* of a number of well-observed meteors which have appeared in recent times, may be taken at thirty-four to thirty-nine miles per second.

Knowing the velocity of a body in the air, the researches of Professors William Thomson and J. P. Joule enable us to obtain some idea of the *heat* produced by friction of a bolide against the air, in its rapid passage through our atmosphere. The temperature ultimately acquired by the moving body is the equivalent of the force with which the particles of air come in contact with it. This temperature is 1° Centigrade for a velocity of one hundred and forty-five feet per second, and goes on increasing with the square of the velocity,—so that the ultimate temperature acquired by a body moving through the air with a velocity of thirty-nine miles per second, will be about 2,000,000° Centigrade. In Dr. Joule's paper recently read at the Philosophical Society of Manchester, *on the meteor of the 16th of February,* 1818, he asks whether, at the known height of bolides, the density of the air is sufficient to account for their brilliant appearances?

Now the *average height* of well-observed meteors, according to Joule, is one hundred and sixteen miles at the moment they are first seen, and thirty-five miles at the moment they explode or disappear. Taking the greater height, one hundred and sixteen miles, and reckoning the decrease of density of the air to be one-fourth for every seven miles, we find that a column of air a mile long, and of one square foot section, at that height would weigh about 0·0003 of a grain. The temperature acquired at the surface of an aerolite of one foot section, moving at thirty-nine miles per second through this mile of air, will be 0·0003 grain raised 2,000,000° Centigrade, or 0·2 grain raised 3000° Centigrade, which would be, doubtless, sufficient to fuse any known substance, and bring it to a state of dazzling brilliancy. An aerolite of one foot section might, according to Joule, have one-fifth of a grain of its surface brought to this condition in its passage of one mile in the one-thirty-ninth of a second, and be thus rendered sufficiently luminous to attract the attention of an observer at one or two hundred miles distance.*

Mr. Alexander Herschel informs us that the height of

* A similar calculation has been previously made by Reichenbach and by Haidinger.

eleven bolides carefully observed in England, in the years 1861 and 1862, were found to be on an *average* one hundred and two miles at their first appearance, thirty miles at the moment of disappearance.

Nearly fifty bolides, observed previous to 1861 in both hemispheres, present the *average* height of sixty-two miles (apparition) and thirty-five miles (disappearance). Shooting stars appear somewhat higher. On comparing some hundred observations made by Secchi, Quetelet, Heiss, and others, it appears that shooting stars almost *invariably* appear at a height of about seventy-three miles, and disappear at about fifty-two miles above the earth's surface. Their velocity seems to be that of bolides. We have already had numerous occasions of observing, that when a bolide penetrates to within fifteen or twenty miles of the earth's surface it invariably explodes with detonations, and lets fall aerolites.

The track or path of a bolide can be accurately determined when several observers, situated in distant localities, have carefully noted the constellations through which they have seen it pass. To determine its height above the earth, it is sufficient that two observers, situate at some distance one from the other, should happen to note accurately, and at the same moment, the position of the bolide in the heavens. In this manner its *parallax* is obtained, and its height calculated by an ordinary astronomical operation. In the case of shooting-stars, whose appearance is more sudden and of shorter duration, this kind of observation is much more difficult; but it has recently been carried on with great success in Germany and Italy, by means of the electric telegraph. We shall have occasion to refer to it again.

Let us return for a moment to the *real diameter* of bolides. I have stated that, so far as the ***solid substance*** of the meteor is concerned, these real diameters appear to have been very much overrated. Alexander von Humboldt was of the same opinion. Taking, for instance, the bolide observed by Dr. Heiss (14th of March, 1863), alluded to in this chapter, we find that he gives an *apparent* diameter of about 8′; at this moment, its brightest period, we will suppose it at a distance of twenty miles only. Now we know that at a distance 206,000 times its dimensions an object subtends an angle of 1″; at a distance of 103,000 times its dimensions an angle of 2″, etc., so that at a distance of 25,750 times it would subtend an angle of 8″. In other terms, a body will have an apparent diameter of 8′ when we are at 25,750 times the distance of its real diameter. But the distance, we have said, is twenty miles, or 35,200 yards:—

$$\frac{35,200}{25,750} = 1{\cdot}36 \text{ yard.}$$

We get therefore 1·36, or $1\frac{1}{3}$ yard, nearly, for the *real* diameter of the bolide, and not 420 metres!

Again, if we take thirty miles as an average distance, and 32′ as the *largest apparent diameter* of bolides, exclusive of radiation,—that is, making them appear about the size of the full moon,—we find for the apparent diameter of 32′, 6437 times the distance of the *real* diameter, and thirty miles being equal to 52,800 yards—

$$\frac{52,800}{6,437} = \text{about 8 yards,}$$

—a very different diameter from that of upwards of five hundred yards assigned to the Orgueil bolide (1864), or that of half a mile supposed by Halley, Blagden, etc., and communicated to the Royal Society. But even these reduced figures only tend to show the absurdity of the above exaggerated dimensions; they cannot give us the *exact size* of the solid body which moves along in the shape of a *meteor* or *bolide,* for those who have seen a piece of magnesium wire burn must have observed how very much greater is the *apparent* luminous globe at the end of the wire, during the combustion, than the fine extremity of the wire itself. The only means we have

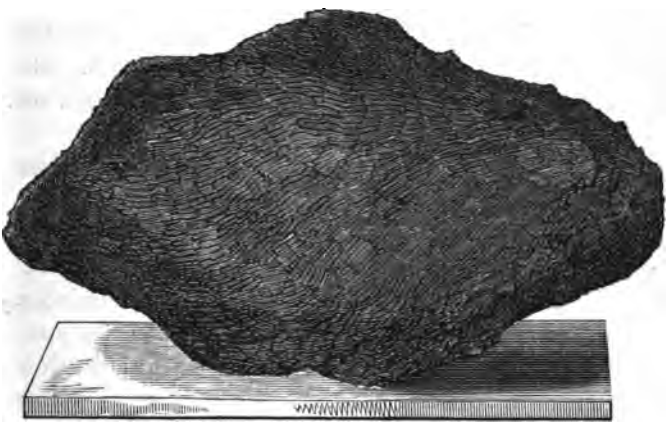


Fig. 13.

Mass of meteoric iron, weighing 2800 pounds, found near Melbourne, Australia: one-sixteenth natural size. For the history of this extraordinary meteoric mass see *Appendix* to this work.

of forming an opinion on this subject, appears to me to reside in an examination of the stones or *aerolites* these meteors let fall upon the earth. Many of the stones are of a terrible size, no doubt, especially some of the metallic aerolites; but even for the largest, their dimensions must be measured by *feet*, rather than by yards. And though it has been asserted that bolides, after dropping several stones, have continued their course in the heavens, in the greater number of cases the *entire meteor* seems to have been precipitated to the earth, either in one compact mass, or in more or less numerously dispersed fragments.

On the 4th of October, 1864, Dr. Heis appears to have seen an *obscure bolide*. As he was observing the Milky Way at half-past eight o'clock in the morning, he distinctly noticed a dark mass proceeding along the half-illumined sky, eclipsing the stars in its path. He was enabled to watch this supposed bolide through an arc of about 11°, when it disappeared.

A somewhat similar observation was made many years ago by Hansteen; it was on the 13th of August, 1825, at a quarter-past eleven in the morning, whilst this well-known astronomer was observing the polar star, that he noticed in the field of his telescope a luminous point in motion. It appeared brighter than the star, its apparent motion was from above downwards, slow and somewhat sinuous. M. Hansteen believes it was a shooting star. On the occasion of this observation François Arago remarked that whilst observing the sun, even through the coloured glass affixed to the ocular lens, he had frequently seen luminous points passing across the field of the telescope; their form was generally very decided, so that they must have been at a great distance. He believes, however, that he has seen these apparitions most frequently about autumn, when flocks of spider's web are wafted through the air. I have myself witnessed similar appearances caused by a displacement of a little dust *within* the telescope.

Besides the phenomena presented in common by fire-ball meteors, or bolides and shooting stars, the latter have been found to appear *periodically* in large numbers or swarms. This periodicity is indeed a most important feature in their history, and will be treated of more or less fully in another chapter.

# CHAPTER XV.

## OBSERVATIONS CONNECTED WITH SHOOTING STARS, ON THE PROBABLE ORIGIN OF THESE PHENOMENA AND ON THAT OF THE ZODIACAL LIGHT.

We have said that the phenomena of shooting stars so *frequently* witnessed at *certain periods* of the year do not appear to differ in any important respect from those presented by luminous meteors or bolides. They manifest themselves only as *smaller* and *more distant* meteors; and some bolides, seen to explode and even to throw down aerolites, have been little larger in appearance than an ordinary shooting-star. But whilst the larger bolides are isolated and rarer apparitions, shooting stars *appear at certain intervals in considerable numbers,* fifty to one hundred or more per hour, for a day or two together, and, in these cases, would seem to *issue generally from one or more fixed points in the heavens.* These facts, which we must discuss presently, are of the utmost importance when we endeavour to account for the origin of the singular phenomena dealt with in this volume. It is here that astronomy is as necessary to unveil the secrets of nature, as was chemistry to unravel the peculiar composition of meteoric stones. Whilst the chemical analysis of aerolites points firmly to a *terrestrial origin,* the equally exact data furnished by astronomical observations point as rigorously to an origin *outside our globe,*—to a cosmical or celestial origin. Our endeavours must be directed towards the combination of these apparently opposite deductions, in the hopes that they may mutually tend, through different paths, to the common goal of truth.

The cause of fire-ball meteors, aerolites, and shooting stars was the subject of conjecture in very remote antiquity, and we find Diogenes of Apollonia stating that "invisible masses of stone move with the visible stars and remain on that account unknown. The former sometimes fall upon the earth, and are extinguished, as happened with the stony star which fell near Ægos Potamos."*

Let me observe here that the most accurate experiments and observations of the moderns often lead us back to the extravagant ideas of the ancients, through the apparently more moderate, but erroneous views of the middle ages. It is a curious instance of "extremes meeting," which the student of historical science cannot fail to notice frequently. The wildest dreams of the ancient philosophers, based upon absolute ignorance or superstition, but supported here and there by direct observation, sometimes approach nearer to that which we, at the present day, consider as truth, than the fiction theories of times much nearer to us.

Even as recently as the commencement of the eighteenth century, the celebrated French chemist Lemery

* For the opinions of the ancients concerning the cause of luminous meteors and aerolites, see Humboldt, 'Cosmos,' vol. i. p. 122; vol. ii. p. 690 note, and vol. iv. p. 568 *et seq.*

did not distinguish fire-ball meteors from ordinary lightning: he says, "Thunder, therefore, ordinarily is produced by a sulphureous wind, that is inflamed and blown impetuously; therefore the places where it passes smell strongly of sulphur; and *sometimes also this sulphureous wind is accompanied with stones.*" Here we have the phenomena of lightning, thunder, and aerolites all mixed up together.*

It was in 1664 that Paolo Maria Terzago published a memoir at Tortona, in Italy, in which he expressed, for the first time, the opinion that aerolites are thrown from the moon,—an opinion which occupied, for ten or twelve years, the attention of the celebrated mathematicians Olbers, Laplace, Biot, Brandes, and Poisson, but since entirely abandoned; whilst another Italian observer, Toaldo, a meteorologist, maintained with several others that shooting stars were produced by the inflammation of a long column of combustible air.

When one of the aerolites which fell at Lucé, in 1768, was sent for analysis to the celebrated Lavoisier, he reported that it was nothing but a mass of iron pyrites, probably altered by lightning and exposure to the air. It was this mistake of Lavoisier's which caused the common nodules of radiated iron pyrites to be called "thunderbolts," an error to which we have before alluded (Chapter IX.).†

Without any previous knowledge (according to Hum-

* Some of Lemery's *chemical* observations are, on the contrary, exceedingly accurate, and in more than one passage his old treatise on chemistry compares *most advantageously* with some of our modern authors.

† For an admirable review of Lavoisier's life and researches, see Dr. Hoefer's charming little work 'La Chimie,' etc., Paris, 1865.

boldt) of the conjecture set on foot by Paolo Maria Terzago, that aerolites may originate in the moon, Olbers, in the year 1795, calculated the amount of initial tangential force that would bring to the earth masses of matter projected from the moon. At that time it was supposed that active volcanoes existed in the moon,—a supposition based upon some extraordinary observations communicated to the Royal Society of London, by William Herschel, in 1787, and again in 1791. He asserted having seen in the non-luminous portion of the moon *three volcanoes in ignition.* So strong was his conviction of the reality of the phenomenon that the day after his first observation he writes, "The volcano burns with more violence than last night," etc. François Arago and other astronomers have shown this to be an illusion, and that the pretended volcanoes were simply points, on the irregular surface of the moon, more illumined than the adjacent parts. In the 'Philosophical Transactions' for 1792, the number of Herschel's volcanoes was no less than *one hundred and fifty !*

Though there are no active volcanoes in the moon, the calculations of Laplace, Poisson, and others, excited considerable attention, inasmuch as they proved that stones projected from the moon with an initial force only about four times that with which a ball leaves the cannon's mouth, would inevitably reach our globe. They might, says Laplace, "become satellites of the earth, describing around it more or less eccentric orbits, and thus not reaching its atmosphere until several or even many revolutions have been accomplished."*

But the view now universally adopted of the original existence of exceedingly small planetary bodies circu-

* Laplace, Syst. du Monde, Belg. ed., 1827, pp. 308-9 et p. 530.

lating round the sun (or round the earth), as first intimated by Chladni many years ago, is undoubtedly nearer to truth.

Chladni supposed that all the accounts of aerolites were founded in reality, and that the planetary velocity with which these bodies enter our earth's atmosphere is quite sufficient to account for the phenomena of light and heat they present, their vivid brightness, and the fusion of the surface of aerolites forming their black rind or crust, which, as we have seen, can be imitated by subjecting the interior of a meteoric stone to the intense heat of a blowpipe flame, in spite of Humboldt's contrary assertion.

The question whether these fire-ball meteors might originate in our own volcanoes has occupied my attention, and, I believe, has been carefully sifted. Concerning the projectile forces of volcanoes, we do not appear to have any observations on which reliance can be placed. From Vesuvius, in 1822, a mass of augitic lava, *many tons weight*, was projected with a *violent explosion*, and thrown *a distance of three miles*; it fell in the garden of Prince Ottajana.* Dr. Peters, who measured this projectile force for Etna, found that the greatest velocity of any stones projected from the crater was only 1250 feet per second. Observations on Peak of Teneriffe gave 3000 feet per second.†

As for *volcanic bombs*, we have already seen that they fall near to the volcano itself, after having penetrated to an inconsiderable height in the atmosphere. However, it may be here remarked that the peculiar phenomena called *ferrilli* by the guides at Vesuvius,

* Lyell's Princip. of Geol., p. 362 (ninth edition).

† See Humboldt, 'Cosmos,' vol. i. pp. 108, 109.

(a name also given to volcanic bombs,) phenomena which appear like streaks of sudden light shot out from the crater and accompanied by violent crackling thunder, deserve to be more thoroughly investigated than they have been.* The extraordinary analogy existing between the chemical composition of stony aerolites and that of our volcanic products cannot be overlooked, and leads us naturally to inquire whether we are absolutely certain that no masses of matter are, at various intervals, shot out through the volcanic craters from the depths of the earth; which masses might revolve round our planet for some days as satellites, and be finally drawn to the surface in the form of fire-ball meteors or bolides. We have yet so much to learn with regard to volcanic activity, its immediate causes, and the effects it is capable of producing, that such questions cannot, in the present state of science, be answered with absolute certainty. But the diligent observations which have now progressed for several years concerning falling stars, and the united labours of Arago, Quetelet, Secchi, Alexander S. Herschel, Newton, Haidinger, Dr. Schmidt, Heis, and many others, have tended to establish the *celestial origin* of meteors and falling stars, and would lead us to consider them as small planetary masses circulating round the sun in closed orbits like that of our earth, and intersecting the earth's orbit at certain points corresponding to certain periods of the year, when these small masses are drawn towards us and exhibit the phenomena of fire-ball meteors or falling stars. Such is the theory now gene-

* See the interesting 'Memoria sullo Incendio Vesuviano del Mese di Maggio 1855," (by Guarini, Palmieri, and Scacchi, originally published in the Rendiconto of the Academy of Sciences of Naples,) Napoli, 1855, pp. 12 *et seq.*

rally admitted by those who have been most occupied with this particular class of phenomena, for a long series of years. We shall have more to say about this theory presently.

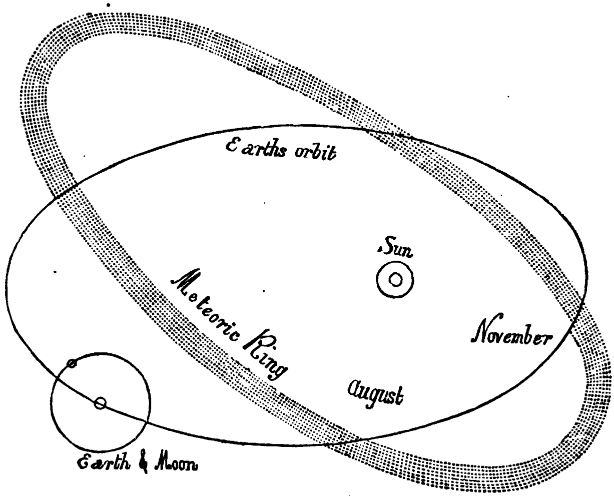



Fig. 14.

Distribution of meteoroids in space. Supposition of one ring.

Falling stars, or shooting stars as they are sometimes called, from the fact of their shooting suddenly across the heavens, often appear like mere luminous points in motion, at other times like a simple streak rapidly vanishing. The largest show both a head, which may appear as large as the planet Jupiter, and a streak many miles in length. They invariably disappear at a distance of several degrees above the horizon, as if completely burnt away during their rapid passage through the higher regions of the atmosphere. Arago was the first to draw attention to the *periodicity* of shooting stars;

that is, to the fact that *they appear in much greater abundance on certain nights than on others.* Two of these periods, that of the 13th of November and that of the 10th of August, are exceedingly remarkable. The latter was discovered by M. Quetelet, of the Royal Observatory of Brussels; the former, by François Arago. Since then several other *periods* have been supposed to exist. The date 13th of November is not absolute; the period appears to extend from the 11th to the 14th. Attention was first attracted to this extraordinary period, 11–13th of November, by the wonderful appearance of falling stars mixed with bolides which occurred on the 12th of November, 1833, and was perfectly observed at Boston, in America, by Mr. Denison Olmsted and Mr. Palmer. The falling stars appeared at such short intervals that it was found imposible to count them; moderate estimations indicate that many hundreds of thousands must have been witnessed that night. They were observed along the entire eastern coast of America, from the Gulf of Mexico to Halifax, and from nine o'clock in the evening till day had dawned on the 13th. In many places some shooting stars, larger than the rest (bolides), were seen in broad daylight, at eight o'clock in the morning. All these meteors appeared to *issue from one point of the heavens,* situated near $\gamma$ *Leonis,* whatever might have been the height of that star at the moment of observation. The number of falling stars was so great, and they appeared in so many regions of the heavens at once, that on endeavouring to count them only gross approximations could be attempted. At the moment of maximum, Mr. Olmsted says there may have been about half as many shooting-stars as there are flakes of snow in the air during an ordinary snow-shower.

When the phenomenon had *decreased considerably*, he counted six hundred and fifty falling stars in fifteen minutes, or about forty-three per minute, and his region of observation included only one-tenth of the horizon. According to this, there must have been about 26,000 shooting stars *per hour*, or 182,000 witnessed in seven hours at Boston, on the night of the 12th of November, 1833,—probably two-thirds only of the real figure.

This grand phenomenon reminded Arago that Humboldt had noticed a considerable fall in 1799, in South America, which was remarked also in Greenland and in Germany. The date was likewise the $\frac{11}{12}$th of November.

Another smaller fall was witnessed in 1832, in Europe and Arabia; the date was the $\frac{12}{13}$th of November. This *November period*, which has occasionally manifested itself by *swarms* of shooting stars, is now fully established.

On the night between the 9th and 10th of November, 1787, many falling stars were observed at Mannheim, in Germany, by Hemmer.

After midnight, on the 12th of November, 1799, occurred an extraordinary fall of shooting stars at Cumana, which was described by Humboldt and Bonpland, according to whom it lasted from two to four o'clock, and was witnessed over a great part of the earth.

On the $\frac{12}{13}$th of November, 1822, shooting stars, intermingled with bolides or fire-balls, were seen in large numbers by Kloden, at Potsdam.

On the night of the $\frac{12}{13}$th of November, 1833, occurred the phenomenon witnessed by Olmsted, and described above.

On the $\frac{13}{14}$th of November, 1834, a similar fall of shooting stars was seen in North America, although the numbers were not quite so considerable. Although Humboldt, up to the year 1852 there had been fifteen cases recorded of considerable and well-observed falls on the $\frac{12}{13}$th of November, namely:—1799, 1818, 1822, 1823, 1831 to 1839 every year, 1841, and 1846. Of these, the most brilliant *streams* took place in 1799, 1831, 1833, and 1834.

The great fall of the $\frac{11}{12}$th of November, 1799, described by Humboldt and Bonpland in the 'Voyage aux Régions Equinoxiales,' lasted, as we have just observed, from two to four o'clock in the morning.

"Upon the whole journey which we made," say these authors, "through the forest region of the Orinoco, southwards as far as the Rio Negro, we found that the enormous fall of meteors had been seen by the missionaries, and in some cases recorded in the church books. In Labrador and Greenland it threw the Esquimaux into a state of utter amazement as far as Lichtenau and New Herrnhut (lat. 64° 14′). At Itterstadt, near Weimar, the pastor Zeising saw the same phenomenon that was at the same time visible under the equator, and near the north polar circle in America." This fall appears, therefore, to have manifested itself over a very large portion of the globe, which does not seem to have happened for several others.

So much for the *November period,* in reference to which Arago said, on pointing it out to astronomers, "We thus become more and more confirmed in the belief that there exists a zone composed of millions of small bodies, whose orbits cut the plane of the ecliptic at about the point which our earth annually occupies between the 11th and 13th of November. It is a new planetary world beginning to be revealed to us." This remarkable passage was written and published in 1835, in the

'Annuaire du Bureau des Longitudes' for the year 1836. It is now generally believed that the *November period* shows itself in its greatest magnificence every thirty-three or thirty-four years, so that we may expect a brilliant show of shooting stars on the $\frac{13}{14}$th of November, 1866 or 1867. This belief is, however, only based upon a remark made by Humboldt, that in 1766 (thirty-three years before 1799) a great fall of stars was seen in Cumana; and by adding thirty-three to 1799, we arrive at 1832, which falls exactly between 1831 and 1833,—and was also a period of considerable splendour.*

Before leaving the November period, it must be stated that, from whatever part of the earth the shooting stars are seen at this period of the year, they are most frequently observed to emanate from a certain point of the heavens, near the constellation Leo, chiefly between the hours of midnight and sunrise. This observation has, at the present time, a great importance in the minds of astronomers, for they are acquainted with other *periods* of shooting stars, and each of these periods appears also to correspond to a given point in the heavens.

The *August period* (10th of August, St. Lawrence's Day) sometimes known as the *Laurentius stream*, is quite as remarkable as that of November. August has been long known to be a month in which shooting stars are frequent. Already in 1762, Muschenbroek, a distinguished philosopher, drew attention to this fact. But M. Quetelet, director of the Observatory of Brussels first placed the matter beyond doubt by stating, in 1836, the probability of the 10th of August being a *period*, and predicting the return of a star-shower for the 10th of August of the next year, 1837. The prediction was

* See further observations on this in Chap. XVII.

realized, and since that time the number of falling stars observed, per hour, on the 10th of August, has always been found to be greater than the number observed, per hour, upon any other night in August. The increase in the number of falling-stars observed over what is seen on ordinary nights extends from 8th to 10th of August, or thereabouts, but the *maximum* occurs upon the 10th with exceeding regularity. Observations extending over a number of years have given Dr. Julius Schmidt as a kind of *average* the following figures :—

| | *Date.* | *Falling stars in one hour.* |
|---|---|---|
| | 6 August | 6 |
| | 7 „ | 11 |
| | 8 „ | 15 |
| | 9 „ | 29 |
| St. Lawrence, | 10 „ | 31 |
| | 11 „ | 19 |
| | 12 „ | 7 |

During the August period the meteors usually appear to emanate from a point in the heavens in or near the constellation Perseus. They are supposed to have a *minimum* of splendour every eight years; thus, according to Mr. A. Herschel, the August phenomenon appears to fail every eighth year, the last minimum having taken place in 1862; "but," adds the same observer, "*the display of the* 10*th of August,* 1863, *is probably the brightest star-shower that has been witnessed in England since the night of November* 12-13*th,* 1832, when it is related that the horses of the mail between York and Richmond were terrified by the brightness of the meteors."

Now in 1839, Heis observed one hundred and sixty meteors per hour on the 10th of August; and if we suppose eight years to elapse between each *maximum* of this kind, we find 1847, 1855, and 1863 for the periods at which this *maximum* should have occurred; such a maximum, therefore, probably exists also, and its next manifestation will no doubt take place in 1871.

Arago was also the first to draw attention to an *April period*, which is still somewhat problematical. He says it was in 1803, he believes on the 22nd of April, that from one to three o'clock in the morning falling stars were seen in prodigious numbers in Virginia and Massachusetts; the phenomenon is described as appearing like a rain of rockets.

It is now supposed by German, English, and American observers that star-showers also occur, but not regularly, on the following dates, to which are appended the respective radiant points:—

| | |
|---|---|
| 2 January | υ Herculis. |
| 9–10 April | δ Virginis. |
| 20–26 April | α Lyræ. |
| 25–30 July | γ Cygni. |
| 15–23 October | ν Orionis. |
| 6–12 December | θ Geminorum. |

Dr. Schmidt observes, "The meteors appear to be the most seldom in January (calculating from the 4th), February, and March;" to which Humboldt replies that he has seen a considerable fall of shooting stars on the 16th of March, 1803, in the South Sea, and that six hundred and eighty-seven years before our era, two meteor streams were seen in China in the month of March. A great number of falling stars were likewise observed in London by my brother, on the 24th of March, 1865.

It will be seen by this that the number of these *periods* is likely to increase considerably. The Germans have distinguished those shooting-stars which appear out of any of these periods by the term *sporadic* (wandering), which may also be applied to bolides or fireballs which show themselves *at all periods of the year*. *Not more* than four to five *sporadic* meteors *per* hour can be expected upon any night which is not a *period*, whilst of *periodic meteors* there may be expected *above fifteen* (to thirty-two, fifty, one hundred, etc.) *per* hour.

It has lately been endeavoured to prove that these *sporadic* stars have also a certain character of *periodicity*. This reminds me of an observation which I communicated to several persons in London in 1864.

On Saturday night, or rather Sunday morning, the 11th of December, 1864, at three minutes to two A.M., I saw a tolerably brilliant meteor; it shot over Putney Bridge, in a direction nearly due south-north, and disappeared in the mist which overhung the northern horizon. The head appeared somewhat triangular in shape; it left no streak in the air, and appeared to have a slight revolving motion like the ball from a cannon. Its appearance was very brief. On referring to my notebook, I found that on the 13th of December of the previous year, I saw at seven in the evening (also from my residence) a small meteor *in precisely the same portion of the heavens*. This one exploded at 20° above the northern horizon, and the head divided into three or four fragments of a red colour. Now these meteors were little more than large shooting stars; but it has been since observed that a bolide sometimes travels exactly in the path of one which preceded it by twelve months, that is, when the earth is again at exactly the same point of her orbit. In 1864 I wrote, "If this theory, which I may be allowed to term the *theory of twelve months' meteors*, is exact, it would tend, together with the *periodicity* of falling stars, to establish the cosmical (or celestial) origin of these bodies."

Now, in 1865, Mr. A. Herschel (in the 'Intellectual Observer') writes thus:—"Not only periodical meteors, but also *ordinary shooting stars*, which may be observed in small numbers every night, [*i.e.* what we have just termed sporadic stars,] are shown to belong to *showers*, many of which [about fifty-six!] at present are as well determined as those of August and November. They return with their attendant radiant points, without confusion or chance, at regular seasons of the year. Although not so rich in meteors, they are even more regular in their return, more constant and long-enduring, than the extraordinary occurrence of star-showers."

We may have very great doubts that these fifty-six periods are "as *well determined* as those of August and November;" but if it should chance to be so, we must probably look upon them as Mr. A. Herschel proposes, namely, "as groups [sporadic groups] circulating round the sun; whilst the meteors of August must compose a narrow ring encompassing the sun, for otherwise they could not return on one and the same date regularly every year. . . . Ordinary or general star-showers, on the other hand, compose belts of vast extent, and must either be the embers of former star-showers now absorbed by the earth, or else the original distribution of meteoric matter round the sun in its primitive unaffected order. We may suppose this matter to have been in a state of dust, or infinitesimal division, so that in general the ordinary star-showers represent the primitive prevailing currents. Occasionally, and at some places, the currents of microscopic dust are found concentrated into shooting stars, and these, by some unknown predisposing cause, have been collected into star-showers. Finally, it would appear that fire-balls themselves are nothing more than the compacted elements of star-showers."

There may be a great deal of truth in these views, however vaguely they are here set forth. Some idea of this theory may be derived from the accompanying figure.—

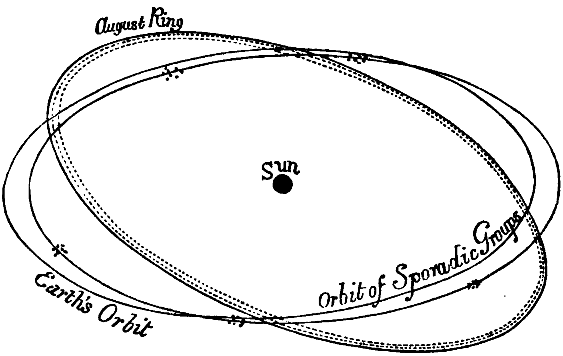



Fig. 15.

Distribution of meteoroids in space. Theory of *sporadic groups* as well as *rings*.

Mr. Newton, in America, who has also devoted many years to this subject, and who ranks among astronomers as an authority with regard to shooting stars, remarks with more caution, that there are *three suppositions respecting the distribution of the orbits of the meteoroids* in the solar system. Either of them may, in the actual state of science, be considered as plausible, and one does not exclude another. These suppositions are as follows:

1st. They may form a number of rings round the sun, like the ring we alluded to above, for the August meteors, cutting the earth's orbit, or passing near it, at many points along its circuit. The *sporadic* shooting stars may be outliers of such rings.

2nd. They may form a disk in or near the plane of the orbits of the planets.

3rd. They may be distributed at random, like the orbits of the comets.

The first proposition has certainly the most adherents. According to it, we have one ring of meteoroids which furnishes us with the August meteors, another through which we pass in November, etc. The position of these rings in space would appear to be very different, for while the November one seems to lie almost in the same plane as that in which the earth's annual course is performed, that of the August shooting-stars seems to be considerably inclined to it, and its nodes (or the points where it cuts the ecliptic) are situated at the extremities of its major axis (see Fig. 16). While the nodes of the August ring seem to be stationary, those of the November ring appear to have a direct proper motion.* Also, according to this first supposition of rings, there should exist a succession of radiant points in the heavens, corresponding to the several rings. Dr. Heis, Mr. R. P. Greg, and others, believe they have detected such a series of radiants. We have already alluded to them in this chapter.

The second supposition would connect the phenomenon of shooting stars with that of the *zodiacal light*. The zodiacal light is that curious luminous phenomenon, differing from the tints of sunset, which appears shortly after the sun has set beneath the horizon. It is observed just before sunrise, or soon after sunset, in the form of an

* On the apparent *retardation* of the November period, see Humboldt, 'Cosmos,' i. 115.

immense lens-shaped disk, placed rather obliquely upon the horizon; its edges, generally very indistinct, rise to a great distance in the sky. Its light is white, like that of the Milky Way. The direction of this lenticular disk is always in the plane of the sun's equator, inclined so that its apex is directed to the Pleiades; it is inclined 7° on the plane of the ecliptic; for which reason it is not

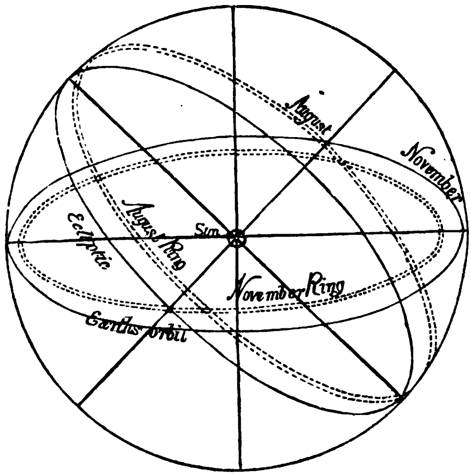



Fig. 16.

Distribution of meteoroids in space. Relative positions of the August and November rings.

seen equally well in all seasons. In our climate, the best time to observe it is, at the spring equinox, about February and March, after sunset, or at the autumnal equinox, about the month of September, before sunrise. (See frontispiece.)

As early as 1730, Cassini believed that the zodiacal light was a nebulous ring, consisting of innumerable small planetary bodies revolving round the sun. He went so far as to suppose that the fall of fire-balls might be connected with the passage of the earth through this nebulous ring; and though Olbers doubts that it has any connection with meteoroids, both Olmsted and Biot have attempted to establish its relation to the November period. Mr. Olmsted, after a long series of observations, has arrived in this respect at the following conclusions :—

1st. That the zodiacal light is a nebulous mass revolving round the sun.

2nd. That the mass extends beyond the orbit of the earth, and that it hovers above this orbit during the November period of shooting stars, making a very small angle with the ecliptic.

3rd. That its periodical revolution is commensurable with that of the earth, in such a manner that it executes an entire number of revolutions while the earth makes one only, and finds itself at the end of the year in the same relative position.

4th. That the shooting-stars of November come from the extreme portions of the zodiacal light, or from a region situated very near its visible limits.

5th. That the zodiacal light, as a whole, has not differed in any respect since the time of Mairon and Cassini (about 1730).

For my own part, I know not whether to side with that most accurate observer, Olbers, or to adopt the ingenious ideas of Cassini, Olmsted, and Biot. I have brought the subject forward somewhat prominently, because we have at present no notion what this said zodiacal light can be, unless it be ascribed to meteoric matter.

# CHAPTER XVI.

## FURTHER REMARKS ON THE THEORY OF SHOOTING STARS, BOLIDES, AND AEROLITIC METEORS.

It must not be supposed that the planetary theory of meteoroids is of very recent date. It is true that many modern writers who have treated of this subject in reports and papers, are apt to neglect entirely the historical portion of their science, and thereby do injustice to many an able thinker. Dr. Chladni, whose name has been already often quoted in these pages, and who certainly originated, in modern times, the scientific inquiry which has since been so actively pursued with regard to the phenomena of shooting stars, etc., had also his opinion as to their origin, and it is from this opinion that the planetary theory professed at the present day has sprung. "As earthy, metallic, and other particles," says Chladni, "form the principal component parts of *our planet, amongst which iron is the prevailing metal, other planetary bodies may consist* of similar or perhaps *the same component parts,* though combined in a different manner. There may also be *dense matters accumulated in smaller masses* [meteoroids], without being in immediate connection with the larger planetary bodies, *dispersed* *throughout infinite space,* and which, being impelled either by some projecting power or attraction, *continue to move until they approach the earth* or some other body, when, being overcome by attractive force, they immediately fall down. By their very *great velocity, which is increased by the attraction of the earth,* and the violent friction of the atmosphere, a strong electricity and heat must necessarily be excited, by which means they are reduced to a flaming and melted condition, and great quantities of vapours and different kinds of gases are thus disengaged . . . ," etc. From the above to the idea of planetary orbits of meteoroids there is only a small step.

In spite of the very enticing appearance of the planetary theories explained in the preceding chapter, to account for the apparitions of shooting stars, fire-ball meteors, or bolides, we cannot forget that, at best, they are but conjectures based upon a series of observations more or less trustworthy, in framing which our modern philosophers appear to have gone a little beyond the boundary of fact.

The ancient astronomers, not knowing that our earth turned upon its axis, naturally supposed the celestial sphere to turn, and the earth to be stationary. They imagined that the stars dropped one by one into the sea, and that, in calm moments, it was sometimes possible, from the sea-beach, to remark at the moment of their disappearance that "they made a slight hissing noise, not unlike that produced by a hot iron when plunged into cold water." So prone was man at that distant period to transfer to the celestial sphere what is really caused by the movement of our own globe. So it may be with the shooting-star astronomers of the present day: they imagine orbits round the sun, when orbits round the earth are, perhaps, quite as probable.

When it was first ascertained with certainty that these aerolites or meteoroids do not come from volcanoes on our earth or in the moon, and when François Arago first hinted at their *periodic* (and therefore *planetary*) manifestations, Humboldt was deeply impressed with the grandeur of the notion that they *came from without*, as the only link which nature seems to have placed between ourselves and planetary space.* He argued, as Sir Isaac Newton and Chladni had done before him, that the matter of our solar system may be all identical with that of our earth; that these aerolites, showing, as they do, no new elements, but the same component substances which we find in the rocks and strata of our own globe, and coming to us, as all observations appear to show, from the regions of the planets, enlighten us upon the chemical constitution of the universe, and lead us to believe that in the matter of our own Cybele exist the elements of all the other planets, nay, perhaps of the sun itself! And, of late years, the probable existence of metals in the sun's atmosphere, deduced from the dark lines of the solar spectrum, would appear to confirm these views. Putting aside the difficulty which such an assumption implies with regard to the density of the different planets (which astronomers are supposed to have ascertained with the utmost rigour†)—of our largest planet Jupiter, for instance, which must therefore be formed entirely of substances that, taken all

* Maybe Kirchhof's spectrum analysis of the sun's atmosphere has furnished us recently with another link?

† See the excellent work of Camille Flammarion, 'La Pluralité des Mondes habités.' Paris, 1864, pp. 111, 112 *et seq.*

together, would almost float upon water,—of Saturn, whose whole substance would float perfectly,—putting aside this difficulty as something which remains to be explained, let us hope, by the researches of a few more years, and admitting that the whole solar system is composed of the same elements as our earth, this does not compel us to assign to meteoroids *orbits round the sun*. What would appear to compel us to admit such orbits is the stability of the August and November *annual* periods, the stability of the radiant points which are supposed, by some, to be well proved.* But these *periods* are augmenting rapidly in number as observation increases, and the *soi-disant* radiant points are increasing in like measure. There exists no longer the sole annual period of November, but numerous others distanced by weeks or months only, for each of which we are compelled to assume a separate ring of these minute bodies round the sun, in spite of the varying positions of the large planets and *the considerable perturbations such rings would inevitably undergo*.†

We know a planet—Saturn—surrounded by several rings, which undergo slight perturbations only; and taking especially into consideration the chemical composition of aerolites, we may be tempted to suppose that these meteoroids have orbits *round the earth*, not round the sun, and that they constitute a series of *dark rings* round our globe, similar perhaps to the rings of

* For instance, by Mr. Glaisher, in his reports to the British Association on luminous meteors; also by Mr. Herschel and several others.

† Are we quite sure that the small planets between Mars and Jupiter, having their courses changed by perturbations, have not been discovered over and over again, and described as new? After all, instead of some *sixty* there may be only ten or twelve?

Saturn. That the zodiacal light may be connected with such rings is not impossible, since we know so little of it. "Great as is the obscurity," says Humboldt,* "which still envelopes the material cause of the zodiacal light, still, however, with the mathematical certainty that the solar atmosphere cannot reach beyond $\frac{9}{20}$ths of the distance of Mercury, the opinion supported by Laplace, Schubert, Arago, Poisson, and Biot, according to which the zodiacal light radiates from a nebulous flattened ring, freely revolving in space between the orbits of Venus and Mars, appears, in the very deficient state of observation, to be the most satisfactory."

The question naturally arises whether a nebulous flattened ring *round the earth* would not present the appearance of a ring "freely revolving in space between the orbits of Venus and Mars." See the two diagrams annexed (Figs. 18, 19),

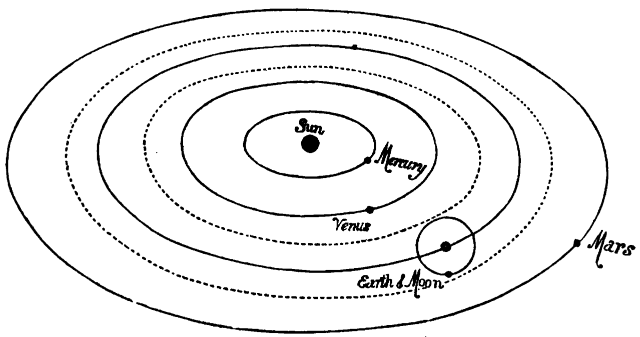



Fig. 18.
Planetary theory of the Zodiacal Light.

* Cosmos, vol. iv. 561.

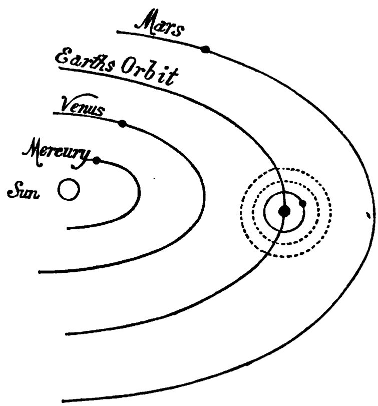



Fig. 19.

Satellite theory of the Zodiacal Light.

It must not be forgotten, as some writers upon the subject appear to have done, that the *planetary velocity* so frequently spoken of (as "greater than that of our earth," etc.,) with regard to meteors, bolides, or shooting stars, *only applies to the curve described by them in reaching the earth* after they have left their primitive position in the orbit (or rings). This curve is very different from the one in which they may be supposed to revolve before they are attracted to the earth's surface; and though it has served the astronomer Petit, of Toulouse, who once believed bolides to be *satellites of our earth,* to calculate, more or less correctly, the orbits of these bolides round the earth, it would be very absurd to use it for calculating an orbit round the sun. Unless the zodiacal light be, after all, the ring of meteoroids it is supposed to be, these bodies move along *invisibly,* and an aerolite or shooting star only becomes *visible* on entering our atmosphers, *i. e. in falling from its orbit.*

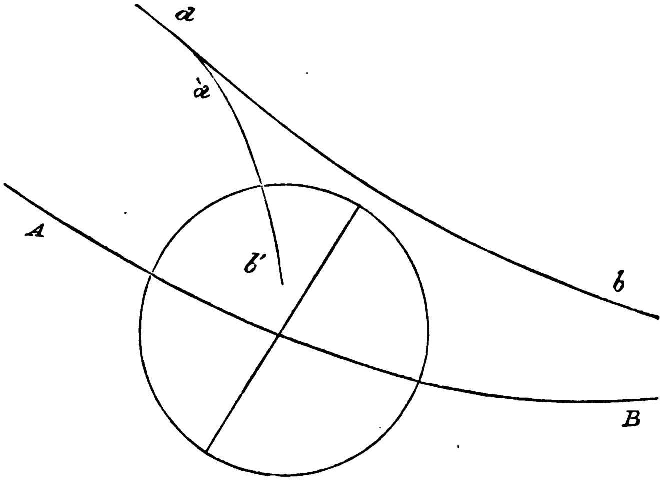



Fig. 20.

Diagram of the fall of an aerolite or bolide.—A B, portion of the earth's orbit; *a b*, portion of the orbit of a bolide or falling star; *a' b'*, curve described by the bolide on falling to the earth, during which portion of its course alone it is luminous (*i.e.* visible).

Other planets may have their invisible rings of meteoroids—matter thrown from them during their period of formation—and the same may be true of the sun itself.* Dr. William Thomson, of Glasgow, one of our most eminent philosophers, has indeed endeavoured to account for the light and heat of the sun, by the constant fall of aerolites upon its surface; and he

* What are the *red protuberances* seen during a total eclipse of the sun? or those extraordinary appearances related in another chapter of this work?

limits this supply to a period of 300,000 years from the present time—a subject I do not intend to discuss here. (See Chapter XX.)

It might be objected to this *satellite theory* (embracing at once meteoroids and the zodiacal light) that the moon's orbit is only inclined about 5° and the zodiacal light some 7° on the plane of the ecliptic, why therefore should not other satellites of our earth, if it has any, show similarly inclined orbits? and if so, how is it that aerolites can possibly reach the earth out of the region of the tropics? In the first place I would reply, that the seventh satellite of Saturn is thrown as far as 30° out of the equatorial plane; in the next, that the earth's attraction being greater near the poles than at the equator would tend to draw an aerolitic mass out of the tropics. A considerable number, however, have fallen in the equatorial regions of the earth.

To complete this satellite theory, we have only to suppose that the swarms of meteoroids revolving round the earth are at certain seasons of the year drawn towards us, and that this happens when the earth occupies with regard to the other celestial bodies certain positions, which remain to be determined. Being composed of very small masses of matter, this ring around the earth must naturally be subject to great perturbations or change of figure. And though the general appearance and position of the zodiacal light does not seem to have changed since 1730 or thereabouts (supposing this phenomenon to be due to a ring of meteoroids), yet the perturbation of its individual component masses may be such as to bring them occasionally to the earth's surface, without causing any change in the apparent position or shape of the ring.

That this meteor ring is composed chiefly of very small masses of matter appears certain from the extraordinary predominance of *shooting stars* (which burn completely away, and pass into an oxidized dust, during their brief passage through the air,) over the large meteors reaching the surface of the earth as aerolites, amidst more or less terrifying phenomena, which are comparatively rare. The latter, as we have seen already, *appear to be quite independent of any periods,* and to fall at all seasons of the year, and at all times of the day and night.* It is estimated that on an average there may be for the entire surface of the globe about one aërolite per day, whilst of shooting stars we have a far greater average per *hour* (see *ante*).

The strongest objection that could be urged against the *satellite theory,* and which would tend, if valid, to establish still more firmly the *planetary theory* generally received, is, that planetary perturbations, though susceptible of accurate observation, are very slight, and require centuries of time to become very appreciable; moreover, that if the meteoroid orbits be subject to these perturbations, have they not already been noticed in the

* Mr. Alexander Herschel, on the supposition that aerolites fall most frequently in the daytime, has conjectured (according to the *planetary theory,*) that their orbit lies inside that of the earth. "It may be presumed," he says, "that the suspected planets (aerolites) are situated within the orbit of the earth, because by far the greater number of aerolites are experienced by day, while the sun is still above the horizon, and the largest detonating fire-balls occur about the time of sunset. In this way, the passing of dark bodies across the disk of the sun, and more rarely across the disk of the moon, may be explained ('Intellectual Observer,' April, 1865). In the opinion of this writer shooting stars and silent bolides are two degrees of the same phenomenon; for, as Humboldt and others have shown, they often appear together (America, 1833, England, 1846, for instance), but aerolites require another explanation.

*retardation* or oscillation of the November period alluded to by Humboldt? To which we may reply, that the perturbations of meteoroid masses circulating in space, either round the earth or the sun, *must be considerable,* since these masses are actually drawn to the earth itself in great numbers.

Such, then, is the theory by which we might perhaps combine the *chemical* and the *astronomical* data we possess with regard to meteoroids. I have brought it forward, in opposition to the received notions, with the view rather of enabling those who are devoting their time to this branch of knowledge to undermine it, and so establish on a firmer basis their own ideas, than with the feeling that it alone should be considered the nearest approach to truth. Indeed, the questions, whether meteoroids revolve round the earth or round the sun, whether there be *one ring* or *several rings,* whether the phenomenon known as the *zodiacal light* represent this ring or these rings, cannot fail to be satisfactorily solved in the course of a few more years of observation, devoted more especially to the various *periods* and *radiant points.*

The chemical portion of this interesting problem has been most completely solved: aerolites are shown to be *of the nature of our earth.* And if we combine for a moment the planetary theory and the fact that the large aerolites fall generally during the day, whilst the large bolides (either silent or detonating) appear usually soon after sunset, and shooting stars (especially the November and August swarms) always at night; moreover, when we consider the chemical composition of aerolites,—we are forcibly drawn to the conclusion that our earth circulates round the sun in or near a *continuous cloud of its own* *dust**—matter thrown from it during the earlier periods of its existence,—and that this dust is distributed in such a manner, that its larger fragments circulate inside the earth's orbit, and gradually decrease in size as they extend beyond this orbit. This distribution in space of the meteoric masses, which gives rise to the phenomena

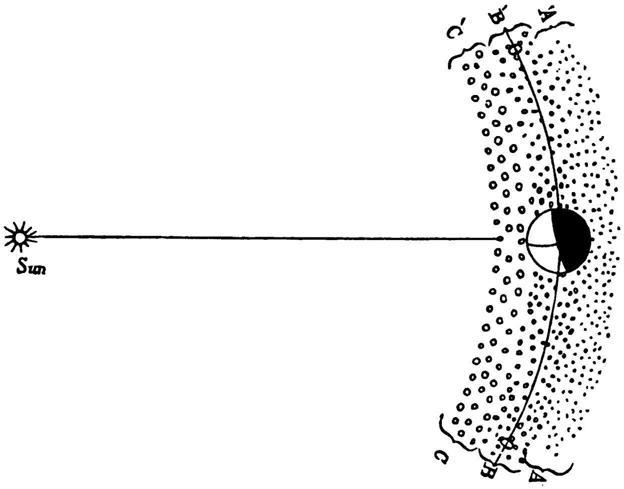



Fig. 21.

Distribution of the elements of a meteoric ring, according to the latest views. O O′, orbit of the earth; A A′, region of shooting stars (night); B B′, region of bolides (evening); C C′, region of aerolites (day).

described as *aerolites, bolides,* and *shooting stars,* may be seen at a glance in the accompanying rough diagram.

We shall now pass on to some miscellaneous observations, which appear to me worthy of attention. As these observations are principally records of facts, allusion to

* "*Dust*,"—I apply the term in comparison between the size of the globe and that of the meteoric masses which have fallen upon it.

any theory in particular will be avoided. After what has been already said, the reader will be able, we trust, to form his own notions, and to choose between the satellite and planetary theories of meteoroids. The concluding portions of this volume may perhaps render his task somewhat easier.

If, in future years, extended observation enforce more and more upon us the truth of the assumption that meteoroids are really *the dust of the earth*—fragments of the earth's mass, thrown from it in its early years (in the infancy of the globe, when volcanic action was intense; probably long after the moon was separated from it,)* which myriads of fragments have continued ever since to circulate along, or near to, the earth's path,—then shall I be satisfied to have originated this theory.

* See the celebrated "*seventh and last note*" in Laplace, 'Système du Monde.'

# CHAPTER XVII.

## MISCELLANEOUS OBSERVATIONS IN RECENT TIMES.

In order to render this volume as complete a history of our subject as can be done without entirely abandoning the popular style in which it has been my endeavour to write it, I find it necessary to group together in this chapter a number of miscellaneous observations, connected with shooting-stars, bolides, and aerolites, which could not have been inserted in the previous chapters without causing much obscurity, and interfering more or less with the plan and object of the work.

In the first place, we must consider here the results of a long series of observations by M. Coulvier Gravier, of Paris, without doubt the most enthusiastic observer of shooting stars in France. We have already seen that the law of periodicity was arrived at by observing for many years consecutively *the number of shooting stars in an hour*. It was in making this kind of observations that M. Coulvier Gravier found—putting aside the exceptional or *periodic* nights (the 10th of August, the 13th of November, etc.)—that there existed an horary number (*nombre horaire*) which augments progressively from six o'clock in the evening to about three o'clock in the morning, then diminishing till daylight, and probably during the whole day, until the next evening. For instance, between six and seven o'clock in the evening, on ordinary nights, we have about six shooting stars; between twelve and one o'clock ten shooting stars; from two to three o'clock seventeen; whilst the number falls again to about thirteen between six and seven o'clock in the morning.

The importance of this ingenius discovery will be at once seen with reference to the *distribution* of the meteoroid corpuscules in space, and tends to confirm the opinion now professed by several observers and already alluded to above, that the larger meteoroid masses circulate *inside* the earth's orbit, whilst the smaller masses, those which occasion the phenomena of *shooting stars*, revolve *outside* our orbit, and therefore appear in greatest numbers on that side of the earth which is turned away from the sun.

With regard to the *period*, 10th, 11th, and 12th of August, which is so rich in shooting stars that about 110 are counted in an hour, it appears to have been noted in the most remote antiquity (see Chapter X.). The 'Chinese Annals,' compiled by Édouard Biot, indicate particularly the years 830, 833, and 835, as having shown a *maximum* number of shooting stars about the end of July, this date being computed according to the Gregorian calendar. When the precession of the equinoxes is taken into account, it is found that in the years 830, 833, and 835, at the moment when the Chinese observed their *maxima* of falling stars, our earth occupied precisely that portion of her orbit in which she is now found on the 10th of August.

M. Coulvier Gravier has extended his untiring observations still further; he recognizes for the 10th of August a *rise* and *fall* in the number of shooting stars observed at this *period,* during a number of consecutive years. In 1800, on the 10th of August, only fifty-nine shooting stars per hour could be counted at Paris, whilst in 1848 we had no less than 110. Ten years later, in 1858, the *horary number* fell again to thirty-eight, since which time it has been progressing gradually, becoming a little greater each successive year. Something similar has been observed for the November period, as I have already stated. Olbers observed a considerable *maximum* on the 12th of November, 1799, when an extraordinary number of shooting stars were seen; the number diminished year after year till it nearly disappeared; then increased until it reached its primitive splendour in 1833, when about 130 falling stars were observed per hour in Germany. As we have before noted, there is a period of thirty-three or thirty-four years between these epochs of extraordinary brilliancy, and therefore a considerable apparition is expected for the 12th to the 14th of November, 1866 or 1867.*

It must be remembered that these observations of Coulvier Gravier and Olbers hold good only for Paris and North Germany,—we may perhaps say for northern Europe generally. Something quite different seems to be going on in other latitudes, and it would appear, from certain observations recently made by M. Poey, that the *rise* and *fall* in the number of shooting stars observed at the August and November periods, do not occur at the same intervals, in the tropics, for instance, as in northern Europe. Of late years, whilst, according to M. Coulvier

* The extraordinary star-shower of 13th November, 1866, as seen in London by the author, is described in the *Appendix.*

Gravier, at Paris the *horary number* has been slowly increasing, at Havana M. Poey has seen so few falling stars that he actually doubts the existence of the August and November periods!

The author of these observations, M. Andreas Poey, the young and laborious Director of the Havana Observatory, has published two papers upon the subject in the 'Comptes Rendus' of the Academy of Sciences at Paris, the one in 1864, the other in 1865. The first throws a doubt as to the existence of an August period in Havana, the second a doubt as to the existence of a November period. The series of observations is rather short, embracing only two years, but it appears to have been very carefully made.

As regards the larger meteors, or *bolides*, they sometimes accompany shooting stars at the periods of the 10th of August and 12th and 13th of November, as we see in the accounts of the August period in England, 1863, and the November period in America, 1833. They also appear to be more especially abundant in the months of *October*, *April*, and *December*. An extensive catalogue, compiled by Mr. Greg, including about 1500 observations of meteors, shows a preponderance of *bolides* on the 10th of August, 13th to the 14th of November, 6th to the 14th of December, 10th of April and 18th of October. On the two latter dates star-showers have been observed. As far as my own experience goes, bolides are observed with tolerable frequency in *August*, *October*, and *December*.

On the night of the 13th–14th of November, 1865, many persons, doubtless, like myself, prepared to make the usual observations. But if their experience has been similar to my own on this occasion, they must have been much disappointed. M. Coulvier Gravier's observations this same night, at Paris, have also been very unsatisfactory. What can all this mean? The phenomenon which appears of late years to have been gradually on the increase both for the August and November periods, seems to me this year (1865) to have sunk, for London, into complete insignificance, and for Paris (where the sky is much clearer) to have become quite stationary! Would not this lead us to suppose, in spite of all theory, that these *periodic streams occur sometimes in the daytime?* I cannot do better than refer those readers who are willing to consider the direction of star-paths in their full complication and periodical recurrence to the admirable remarks upon the subject in volume iv. of Humboldt's 'Cosmos.' We find here eight or nine epochs of periodic meteor-streams recommended to the industry of observers. "The streams of different months," says Dr. Schmidt (in 'Cosmos,' vol. iv.), are not alone different from each other; in different years, also, the abundance and brilliancy of the same stream varies in a striking manner."

In a paper read not long ago by Mr. Newton, before the American National Academy of Sciences, from which we have already extracted the opinion of this author upon the *distribution* of the *orbits* of meteoroids in the solar system, we find other considerations which it is necessary to note here. In this paper Mr. Newton considers also the *number* of shooting stars that come into our atmosphere each day, and are *visible to the naked eye*, and the *number of telescopic shooting stars*. The average number of the former, that is, of shooting stars which traverse the atmosphere daily, and are large enough or near enough to be seen with the naked eye, on a dark, clear night, he calculates to be no less than 7,500,000, and if we include with these the telescopic shooting stars, Mr. Newton assures us their number will amount to about 400,000,000. Taking into account the volume occupied in space by our earth and its atmosphere, the author tells us that in each such volume of space traversed by the earth there are about 13,000 small bodies [*dust*] each of which would furnish a shooting star visible, in favourable circumstances, to the naked eye, and if telescopic meteors be counted also, this number must be increased forty times at least.

But Mr. Newton does not stand alone in these extraordinary numerical conjectures. Professor Twining, who is of opinion, it appears, that meteoroids circulate round the sun in *oné* vast ring, asserts that the diameter of this ring is nearly equal to that of the terrestrial orbit, on which it is inclined 96°, has a thickness of two to five millions of leagues, and is composed of three hundred thousand *millions* of corpuscules, which circulate round the sun in two hundred and eighty-one days. Supposing each of them to have, on the average, a diameter of about one yard, and that they were all united into a single mass, they would form a globe not more than one-tenth the size of our earth.

These conjectures are, of course, far beyond the reach of any experimental proofs, at least for the present. If we suppose, *for London alone*, ten shooting stars per hour as the average for every night in the year, it gives us two hundred and forty shooting stars for the twenty-four hours. And Professor Secchi has recently called attention to the small horizontal distances to which these appearances are limited. To quote his own words, " the cases in which this exceeds two hundred and twenty kilometres (or about one hundred and thirty-two miles), are rare." So that at places double that distance apart, it is scarcely possible that the same shooting-stars can be seen. And again, if we suppose the celestial vault represented by a globe fifty centimetres (twenty inches) in diameter, we may safely assert that the part of the sky whence the meteors proceed, does not exceed the space that might be covered by a shilling."

However, after what has just been said of the prodigious numbers of shooting stars, which burn away like so much magnesium-wire on passing into our atmosphere, and slowly find their way to the earth's surface, in the shape of *dark-coloured mineral dust,* it is not surprising that Baron von Reichenbach, who has already devoted much time and attention to meteoroids, should latterly have endeavoured to recover some of this meteoric dust. The result of his researches are given in the journal 'Cosmos' (29th of December, 1864). Proceeding to the summit of the Labisberg, and other small German mountains, ranging between one and two thousand feet high, Herr von Reichenbach collected, here and there, a few handfuls of earth, carefully taken from spots which human labour had never attained. On submitting these specimens to analysis, he finds they all give slight traces of nickel and cobalt—elements which, we have seen, are usually present in meteoric masses, but are tolerably rare in the various minerals scattered on the surface of the earth. The quantity of nickel found in these analyses is estimated by Baron von Reichenbach at $\frac{1}{10000}$th of the weight of soil analysed. It would be interesting to see these experiments repeated in England, or in the north of France. The German soil of these small hills may contain some nickel not derived from meteors. All the nickel of commerce, used to make our "German-silver," comes to us from Germany; and stones, which the author of this work has taken with his own hands on the hills of Waldeck, have been found, on being analysed, to contain both nickel and copper. In Baron von Reichenbach's assays, he usually found nickel and cobalt; once he found no cobalt, but some copper.

We may also call attention here to some curious observations published by Herr von Reichenbach in 1859, and given in the journal 'Cosmos,' the 22nd of April of that year (vol. xiv. p. 445). Instead of one aerolite per day for the whole earth (generally admitted in England), this author says *twelve aerolites,* at least, fall somewhere on the earth every day, or 4500 *per annum.* "Many of them are very small, but others are masses of considerable size." In the paper ('Cosmos,' *loc. cit.*), the author enters into some ingenious considerations, which tend to prove that *comets* are neither gaseous nor liquid matter, but similar in composition to the aerolitic masses which fall upon our earth.* In fact, comets, in Baron von Reichenbach's idea, are merely vast *swarms of meteoroid matter* in a state of *dust,* and he upholds this view by referring to their action on light. The tail of comets, and even the nucleus, is transparent, the rays of light which pass through them undergo no refraction, therefore the cometary mass is neither liquid nor gaseous; their light is polarized, and is simply solar light reflected. A comet is therefore composed of a mass of isolated *solid* grains," etc. . . . .

* Baron Reichenbach has no less than one hundred and seventy-six specimens of aerolites in his private collection, one of the richest in the world.

# CHAPTER XVIII.

## ON THE COMBUSTION AND EXPLOSION OF METEORS IN THE AIR.

In Chapter XIV. we have given Professor J. P. Joule's estimate of the heat acquired by a meteor passing through the higher and most rarified portion of the atmosphere. As we then stated, Professor Joule was not the first to turn his attention to this kind of calculation. As early as 1848, Sir John Herschel gave a slight notion of it in the 'Edinburgh Review;' it was taken up again by Professor Haidinger, in 1861, and again by Herr Reinholds Reichenbach, in 1863.

As soon as a bolide, drawn towards the earth with an enormous velocity, comes in contact with the atmosphere, it immediately meets with a resisting medium which slackens its speed. This resistance is very considerable on account of the great rapidity with which the meteor moves. According to the authors already named, the amount of this resistance can be calculated with tolerable accuracy, and in Herr Reichenbach's opinion it would be sufficient to stop, in the space of ten seconds, the course of a cannon-ball propelled at the rate of sixty miles a second. Let us suppose that a bolide loses only $\frac{1}{100}$th part of its speed from this cause; the immediate consequence is the development of a corresponding amount of heat, which can also be calculated with accuracy, and is employed to raise the temperature of the bolide itself or of the air which surrounds it. Reichenbach admits that the slackening of the speed of a bolide $\frac{1}{100}$th during its passage through the atmosphere is sufficient to raise its temperature 75,000° Centigrade, if it retains all the heat itself, or 5000° only, if it loses heat by radiation as soon as it is engendered. The actual heat of the bolide is then confined between 5000 and 75,000° Centigrade, which surpasses any temperature we can produce artificially. In these circumstances, the surface of the meteorite melts and forms that dark vitreous enamel with which meteoric stones are invariably covered, and which may be said to characterize them. At a heat of 5000° iron and carbon burn with evolution of brilliant sparks, and all known substances would be reduced to incandescent vapour, The meteorite therefore appears in flame, and is followed by a train of fire, which gives to it the aspect of an ordinary rocket. This train soon becomes extinguished, but the substance which produced it remains suspended in the air, and in the day-time appears like a permanent cloud.*

If the meteorite is of small dimensions, which is most usually the case, its substance is *entirely* burnt by its passage through the air, we see a star which falls—a shooting-star,—and all is over. When the bolide is larger, the phenomenon lasts longer, passes over a great portion of the earth's surface; it pushes before it the column of air on its route, which it compresses and renders incan-

* Compare Jamin, in 'Revue des Deux Mondes,' July 15th, 1864.

descent, and leaves behind it a partial vacuum which this condensed air rushes in to fill. As we have already seen, when speaking of *real* and *apparent* diameters of meteorites traversing the atmosphere, it is this luminous atmosphere which causes the bolides to appear much larger than they are in reality.*

Now the *explosion* of meteors is accounted for in the following manner by Reichenbach, and his explanation is admitted by many others. Let us, therefore, examine it first:—

Whilst a bolide compresses the air before it, it of course experiences an enormous pressure upon its surface. If we wish to acquire some idea of this pressure we have only to notice what occurs in fearful hurricanes, when the wind rushes on at the rate of forty to fifty yards per second, or presses with a weight of about thirty-eight pounds upon every square foot of any surface presented to it. This would be the pressure sustained by a bolide having one square foot of surface and shot through a calm atmosphere at the rate of forty to fifty yards per second. But if, instead of forty yards, the velocity is some 40,000 or more, the pressure sustained will, of course, be enormous. At the height of seventeen miles it will be about seven hundred atmospheres, according to Reinholds Reichenbach. Iron alone can resist such a pressure without being crushed to pieces; therefore most meteorites fly to pieces, like a stone flung violently against the wall. The explosions and rumbling thunder-like noises are the result of the sudden compressions and shocks received by the air, such as occurs on a small scale in the firing of a gun.

The arguments against this theory advanced by

* See Chapter XIV.

Sæmann (in 'Comptes Rendus' of the Academy of Sciences, Paris, No. 1, 1864,) on the occasion of the fall of stones at Tourinnes-la-Grosse, Belgium (7th of December, 1863), which came to the earth with a *very moderate velocity*, as we have already seen, have no weight whatever. They apply only to the fall of the stones from a meteorite which has exploded, that is, which has come to the end of its course through the atmosphere; and it is natural to suppose that the velocity with which stones arrive at the surface of the earth from an exploding meteor may be very different from the velocity of the meteorite itself in the air. Indeed, in connection with this question of *velocities*, we may, without much repetition, notice here three kinds of velocity quite independent one of the other, viz.:—

1st. *The velocity of a meteorite in its orbit* round the sun, or round the earth, which is *unknown*, and can only be estimated by the wildest conjectures.

2nd. *The velocity of a meteorite which has left its orbit*, and is drawn towards the earth; this can be calculated with accuracy, the course of the meteor being visible, and invariably *hyperbolic*; this is the velocity which is so often stated to be "greater than that of the earth in its orbit," generally thirty to thirty-five miles per second.

3rd. *The velocity with which the stones fall to the earth* from a meteorite that has exploded, that is, the course of which is run in the atmosphere. This velocity will depend greatly upon the height at which the meteor exploded; it is therefore *variable*.

The theory of the explosion of meteors given above, is, I believe, generally accepted, and no doubt it goes far to explain the whole phenomenon of detonations presented by them. I have, however, long held another opinion which, though not excluding that of Reichenbach, may probably account also for these explosions. There is no doubt that the surface of a meteorite, passing through the air at the enormous rate of some thirty miles per second, becomes *very rapidly heated* to an enormous degree. Now, if we take a little ball of phosphorus, chlorate of potash, and gum, such for instance as the head of a common lucifer match, and heat it quietly, we find that it takes fire and burns vividly, but *without explosion*, when the temperature has attained a certain degree. But if we take a similar little ball and plunge it into a hollow space in an ordinary fire, where it becomes *suddenly heated at the surface*, to a degree much higher than is necessary to inflame it, we find that *it explodes*. Now this is precisely what occurs with meteorites; their *surface* is *rapidly heated*, to an excessive temperature, and therefore tends to dilate, and to tear the substance of the stone to pieces before the heat has penetrated to its interior. The thin black crust or enamel produced upon them, shows to what a slight depth the heat penetrates into their mass.

It is curious to note that the meteoric stones of Quengyouk, in Pegu, which fell on the 27th of December, 1857, fit very exactly to one another at the surfaces not covered by the black enamel, although these fragments were picked up more than a mile apart. Five meteoric stones, which fell on the 12th of May, 1861, near Gootka, in India, and weigh together upwards of thirty pounds, being joined together by their uncoated surfaces, fit so exactly into one large uniformly crusted mass, that, according to Mr. Herschel, two fragments only are wanting at the angles; and these five stones were found from two to four miles apart. Sections of this meteorite and its model are to be seen in the British Museum. Some modern authors would lead us to believe that meteors which do not penetrate into the earth's atmosphere until they come to within about twenty miles of the surface, rarely or ever explode, whilst those which come to within about twenty miles of the earth's surface almost invariably explode with more or less violence. Now this law is not absolute: I have already in these pages described the explosion of a shooting star which must have been some sixty or seventy miles distant (see Chapter XIV.), and I have here to describe a meteor that I saw at Moffat, in Dumfriesshire, on the 3rd of October 1865, and which exploded at a distance of about seven miles only! In some of the previous chapters of this work we find several examples of detonating fire-balls, whose explosions were heard very shortly after the meteor was seen; most frequently, however, the detonations are not heard until a considerable interval has elapsed.

It was on the 3rd of October, 1865, at nine o'clock in the evening, that I was walking across the little town of Moffat, in Dumfriesshire, on the way to the post-office, when a brilliant meteor appeared suddenly in the northern heavens, directly under the stars of the *Great Bear*. It spread a very vivid light, in spite of the moon near full; it was of very short duration, and was seen to explode before it disappeared,—in fact, almost the moment I saw it (see Fig. 22). This bolide was of a moderate size; it appeared and exploded very suddenly, N.N.W. of Moffat, directly under the tail of the *Great Bear*. In about thirty seconds from the moment it was seen to explode, my wife and I distinctly heard the report of the explosion. It was a single report like the distant fire of a file of infantry, or like the blasting of a

Fig. 22.

Explosion of a meteor, as seen by the author, on the 3rd of October, 1865, at Moffat, in Dumfriesshire.

mine some distance off. Thirty seconds gives for this small but brilliant bolide a distance of about seven miles. If the meteor in question let fall any stones, they will be found some two miles beyond the hills which are seen in a N.N.W. direction, about five miles from the town.

# CHAPTER XIX.

## THE HEIGHT OF OUR ATMOSPHERE AS DEDUCED FROM THE OBSERVATION OF METEORS, AND BY OTHER MEANS.

An extremely interesting question presents itself here, regarding the height to which our atmosphere extends above the surface of the earth. Hitherto it has been supposed that at a height of forty to fifty miles the elasticity of the air and the attraction of gravitation balanced each other. Applying to the total height of the air the law of diminution of density observed in the lower strata, we arrive at the conclusion that at a height of about forty-five miles the air must be as rarefied as it is in the exhausted recipients of our best air-pumps. However, we know nothing, or next to nothing, with regard to the absolute height of our atmosphere. It is therefore interesting to compare the conjecture (of forty-five miles) furnished by the barometer, and law of diminution, with the results towards which we are led by the observation of the heights of meteors, and also with those obtained lately by means of the polarization of light.

"The atmosphere," says a recent writer, Dr. Buist, "forms around the earth a spherical envelope, the thickness of which *is unknown*, the rarefaction of the higher strata increasing as the pressure diminishes. Numerous observations indicate, however, that the limits of this envelope cannot be situated at a height of less than fifty miles, nor extend to more than 500 miles." The margin is rather wide !

Now it is certain that neither shooting stars nor the *aurora borealis* can produce any light but by means of the air, however rarefied. In fact, for aurora streams a highly rarefied condition of the higher portions of the atmosphere is a necessary condition.

Poisson, in his well-known work 'Recherches sur la Probabilité des Jugements,' published in 1837, supposing that meteors shone in an absolute vacuum situated beyond our atmosphere, states that he cannot account for their luminous appearance by friction against the air, but probably by supposing it to be the effect of electricity. He admits the existence of an envelope of electricity outside the atmosphere, into which the meteorites plunge and become luminous by the electrical disturbance thus produced.

Quite recently M. Quetelet, the learned Director of the Observatory of Brussels, has reproduced this idea of Poisson's, admitting in place of the electrical envelope, an envelope of highly rarefied and calm air. Sir John Herschel reproduced Poisson's notion rather earlier than M. Quetelet, and this idea of a second and highly rarefied air, extending high above the atmosphere in which we live (the latter being supposed to occupy only the first fifty miles), has found several partisans, though it appears to me exceedingly hypothetical and unnecessary. Mr. H. A. Newton, of Newhaven, asserts boldly "that there must be some kind of an atmosphere at a height of about 500 miles; the streamers of the great aurora borealis of 1859 were about that height."*

Instead of forty-five miles, the height assigned to the atmosphere before the problem was endeavoured to be solved by noting *the greatest heights at which shooting stars are visible,* let us see what the latter observations give us.

In order to determine the height of a shooting star we must obtain its parallax, that is, two observers, situated at a distance of several miles (Rome and Civita Vecchia, for instance), must witness it simultaneously, and note accurately its position in the sky. That they do observe the same falling star simultaneously is known by the telegraph, the one observer signalling to the other the instant he perceives it.

Now, the shooting-stars observed at Rome by Professor Secchi and Signor Statuti, with the aid of the telegraph, some four years ago, gave us an approximate *minimum* height, *forty-eight miles.* The Roman base-line for these observations extends from Rome to Civita Vecchia, a distance of forty miles, sufficient to cause the same shooting-star to be seen (by the two observers) in different constellations. In August, 1864, Professor Secchi's observations were recommenced, and a condensed account of them was published in the English journal the 'Reader' (21st of January, 1865). They began on the 5th, and lasted till the 10th of August. Generally speaking, the parallax of the smaller meteors was less than that of the brighter ones, proving that the latter are nearer to us. On the 10th of August, the

* In the journal 'Cosmos,' of the 7th of January, 1864 (vol. xxiv. p. 34). I myself witnessed this aurora in Paris; its streams were seen as far south as Rome.

parallax was greater (the meteors were nearer) than on any other evening,—*a fact which may account for the greater number seen at this "period."*

The mean height of the meteors at their first appearance comes out in round numbers at *sixty miles*. Out of fifty-six meteors observed at the two stations, twenty-seven were found to be *from forty-eight to seventy-two miles* high; three meteors appeared more than *one hundred and thirty-two miles* above the earth.

Some similar observations, made eight years ago at Paris, by M. Leverrier (the two stations being Paris and Orleans), showed that shooting stars shine at a great height; only some five or six were observed simultaneously at both stations; but the observations were made, we are told, with the greatest care. Some of these gave heights of *more than three hundred miles*,—probably an erroneous result.

It will be seen by this, in what an unsettled state is the question of the height of our atmosphere. If now we turn to the polarization experiments of M. Liais, a well-known and accomplished astronomer, we find the question in perhaps a more advanced state.

In his voyage from France to Rio de Janeiro, M. Liais paid much attention to the rising and setting of the sun. Whilst studying the phenomena presented by sunrise,* he discovered in the eastern sky, just as the first rose-coloured arc announced the commencement of the aurora, and whilst the stars of sixth magnitude were yet visible, a polarization of light in a plane passing by the sun. This *vertical* polarization rose gradually, and attained the zenith when the sun was 18° 5′ below

* His observations are printed in 'Comptes Rendus,' January, 1859; also in 'Cosmos,' *id.*, and the 'Ami des Sciences,' Jan. 23rd, 1859, p. 55.

the horizon. It then gradually moved on towards the west. The *horizontal* polarization did not appear in the west till much later,—not until the sky was glowing with a rosy tint. It must be remarked that the *direct* illumination by the sun giving rise to a polarization passing by the sun, and illumination by the atmosphere causing a horizontal polarization, it results that the sun begins to light up *directly* the higher regions of the air at the zenith, as soon as it is at 18° 5′ below the horizon. In this case, horizontal refraction intervenes twice, to diminish the inclination of the solar rays. On account of this refraction, the sun, at 18° 5′, sends rays to the higher regions of the atmosphere, as if it were at 16° 59′ only. Now, in order that the sun may light them up in these condititions, the "higher regions," must be two hundred and ninety-one kilometres (one hundred and seventy-four miles) high. And this must be the *lower limit*, for, in the calculation, it is supposed that the sun's rays pass close along the surface of the earth, whereas it is more probable that they pass above the thick atmosphere charged with vapour (all lower than this being absorbed), which produces the first crepuscular arc, the height of which thick atmosphere, calculated at eighteen miles, gives $174+18=192$ miles. Arrived at Rio, M. Liais subjected his calculations to the most scrupulous examinations, and arrived finally at the conclusion, that the *height of the atmosphere must be estimated at about two hundred miles English.*

Several conversations which I have had with the late much lamented Admiral FitzRoy, our most eminent English meteorologist, convinced me that he was well aware of the recent attempts to ascertain the height of the atmosphere by observations of shooting stars, at the time of the publication of his 'Weather Book' (second edition). What he says there with regard to the height of the air is as follows :—

"Some think it extends indefinitely upwards, some suppose it twenty miles high or deep, others fifty. Aeronauts and mountain travellers have proved that air, in which man may live, does not extend to ten miles from our ocean level, probably not to eight."*

To return for a moment to this question, as investigated by the determination of the height of shooting stars. The subject is not so new as it has appeared to some, since the publication of M. Quetelet's remarks. Julius Schmidt † says, the *upper* limits of the *height* of shooting stars cannot be ascertained with accuracy; and Olbers considered all heights above one hundred and twenty miles as very problematical. But a falling star, seen simultaneously at Berlin and Breslau, on the 10th of July, 1837, had, according to Heis, a height of *two hundred and forty-eight* miles when it first became visible, and a height of one hundred and sixty-eight miles when it disappeared. Others disappeared during the same night at a height of fifty-six miles. We have also a curious series of observations of this sort, made by Brandes, as early as 1822. From one hundred well-defined shooting-stars, seen simultaneously from two points of observation, four had an elevation of only *four to twelve miles;* fifteen, between twelve and twenty-four miles; twenty-two, from twenty-four to forty; thirty-five (or nearly one-third), from forty to sixty miles; thirteen, from forty to eighty miles; and only eleven (scarcely one-tenth), above eighty miles,—their heights

* 'Weather Book,' second edition, p. 223.

† In Humboldt's 'Cosmos,' vol. iv. p. 583.

being between one hundred and eighty and two hundred and forty miles.

In concluding this subject, which is likely to occupy attention for some time, and which is intimately connected with the much discussed question as to whether our atmosphere has a limit or not,* we must once more turn to the indications furnished by the barometer. At ordinary temperatures air being 11,000 times lighter than quicksilver (mercury) it is evident that if the atmosphere were of uniform density, its height, inferred from the barometer would be 11,000 times thirty inches, or a little more than five miles (5·208) miles. But the density of the air, being proportional to the pressure upon it, diminishes with the height, the higher regions being always more expanded than the lower strata on which they press. At 11,556 feet above the level of the sea, or 2·705 miles, the density of the air is calculated to be one-half that which it is at the surface of the earth,—in other words, its volume is doubled; and if we again halve the density (or double the volume) for every 2·7 miles of additional elevation, we may construct the following table, given by Mr. Graham, in his 'Elements of Chemistry' (vol. i. p. 325):—

| *Height above the sea.* | *Volume of the air.* |
|---|---|
| 0 | 1 |
| 2·705 miles | 2 |
| 5·41 „ | 4 |
| 8·115 „ | 8 |
| 10·82 „ | 16 |
| 13·424 „ | 32 |
| 16·23 „ | 64 |

* In other terms, whether gaseous bodies, subjected to no pressure, can expand indefinitely,—a question in which M. Babinet, member of the Institute, told me he took much interest in 1859, and which has not yet been solved.

And so on *ad infinitum.* Where to stop is the question! Is there a natural limit? Let us see how Mr. Graham solves this important question. "It [the atmosphere] is *certainly* limited," says he (*loc. cit.*), "probably from the expansibility of the aerial particles having a *natural limit.*" We are here referred, by the Master of the Mint, to p. 76 of his 'Elements,' where we read:—"These particles are under the influence of a powerful mutual repulsion, as is always the case with gaseous bodies, and therefore tend to separate from each other; but as this repulsive force diminishes as the distance of the particles from each other increases, Dr. Wollaston *imagined* that the weight of the individual particles might come at last to balance it, and thus prevent their further divergence."

The solution of the problem which occupies us, *the height to which our atmosphere extends above the surface of the earth,* is, in the present state of science, at some distance from us.

Whilst considering these questions several years ago I sketched a *theory of the elasticity of atoms,* never completed sufficiently for publication, in which it was argued that *elasticity,* a recognized *property of matter,* must extend to the *atoms* of bodies; this would explain the impossibility of obtaining, even by the aid of our best machines, anything approaching to a perfect vacuum.

The great height at which the streams of *aurora borealis* manifest themselves may be also deduced from observations of shooting stars:—A beautiful northern light was visible at Bremen, on the night of the 13–14th of November, 1838, at the time of the periodic fall of shooting stars observed by Olbers. This *aurora* covered a large portion of the heavens with an intense blood-red light. The shooting stars which darted across this region were observed to maintain their white colour unaltered, "whence it may be inferred," says Humboldt, "*that the northern light was further removed from the surface of the earth than the shooting stars were* at the point where they became invisible."*

Ferdinand von Wrangel, who travelled along the north coast of Siberia, in the years 1820 to 1824, more than once related to Humboldt the curious fact observed by him in this high latitude, that during an *aurora borealis* certain portions of the heavens which were not illuminated, lit up and continued luminous whenever a shooting star passed over them.†

On the 10th of August, 1852, a great number of shooting stars were observed by M. Quetelet, M. Bouvy, and M. Dupré, at Brussels and at Ghent. At both stations the observers remarked certain *instantaneous illuminations*, similar to electric radiations, which shot through the air from time to time. The Abbé Moigno, writing on this subject in the journal 'Cosmos' (vol. ii. pp. 66 and 67, 1852), remarks that the phenomenon of the *aurora borealis* often accompanies the periodic apparition of shooting stars, and may perhaps be explained in the same manner as the *instantaneous illuminations* just mentioned, by supposing that the meteoroid "dust" through which the earth is supposed to pass at these periods, becomes at certain intervals suddenly electrified by the earth's influence, etc. We should be glad to know upon what facts the learned Abbé founds his conjectures.

However this may be, there is no doubt that the con-

* 'Cosmos,' vol. iv. p. 583. † Ibid., vol. i. p. 114 and note.

nection which appears to exist between shooting stars and the aurora borealis, may one day aid us in representing mathematically the height of our atmosphere; it constitutes a very interesting branch of inquiry, leading to the discussion of several other physical phenomena hitherto little known.

It may be as well to note here that, the height assigned to the atmosphere by M. Bravais, the well-known astronomer, as deduced from his observations on *twilight*, was sixty-nine miles; similar observations, made by Lambert, gave ninety-six miles,—figures which differ considerably from those adopted by M. Liais (*vide supra*). Laplace, in his celebrated 'Exposition du Système du Monde,' says the solar rays reflected from the molecules of air before the rising and after the setting of the sun, forming what we call the *aurora* and the *twilight*, which spread to more than 20° from the sun, prove to us that the most distant molecules of the atmosphere are *at least* thirty miles high."

If we suppose, for a moment, that a given volume of air, considered at the surface of the earth, increases as we rise, according to the squares of the distance, the volume which corresponds to a distance of 4·5 to 5 miles, where (the density, or volume, of the air remaining unchanged) the barometer would be at 0 (that is, where all pressure ceases), would be about 34,656 cubic miles, the cube root of which gives about thirty-two and a half miles as the height of our atmosphere,—a result very similar to Laplace's *minimum* just alluded to.

If it should, one day, be proved that shooting stars can, as Poisson supposed, become luminous in a "vacuum," or that the parallactic observations of these meteors are essentially erroneous, and finally, that the twilight and polarization observations are rendered inexact by refraction, etc.,—this last figure, deduced from purely physical data, may perhaps represent more nearly the true height to which our atmosphere extends above the surface of the earth.

# CHAPTER XX.

SUPPOSED INFLUENCE OF METEORIC STREAMS ON THE EARTH'S TEMPERATURE, ON THE LIGHT OF THE SUN, AND ON THE HEAT OF THE SUN.—THE RING OF THE PLANET SATURN, IS IT COMPOSED OF METEORITES?

BEFORE bringing the present volume to a close, we have yet to examine one or two circumstances, intimately connected, or supposed to be so, with the phenomenon of shooting stars or meteoric streams. It was Brandes who, at the beginning of the present century, first pointed out the occurrence of something unusual in the temperature of the air, which takes place regularly about the 12th of February. In 1834, the astronomer Mädler again drew attention to abnormal temperature, an unusual degree of cold, about the 12th of May; and in 1840, Erman, a German meteorologist, ascribed these *cold days* of the year to the obscuration of the sun's disk by the passage across it of a stream of meteors. Chladni also attributed to a passage of meteors across the sun's disk the extraordinary obscurations of this luminary, which are stated by old writers to have occurred for some hours in the year 1090 and 1203, for three consecutive days in 1547, and again on the 12th of May, 1706. The two latter dates were also made use of by Erman in his paper, to explain the phenomenon of *cold days*. The subject has recently been brought again before the Academy of Sciences at Paris, by M. Ch. St. Claire Deville, who, in support of Erman's theory, brings forward the mean temperature of abnormal cold and warm days in Paris, from 1806 to 1863. This elicited from M. Faye, the distinguished astronomer, an elaborate paper ('Comptes Rendus,' 3rd of April, 1865), in which he points out, with what caution Professor Erman's data must be received. As to the obscurations of the sun's disk, M. Faye shows that some of these narratives are quite devoid of authenticity, and that the others evidently relate to purely *local darkness*, such as might be produced by fog or mist in the air, and was not observed at any distance. From the period of Cæsar's death to the present time, we find in various works no less than fifteen cases of obscuration of the sun's disk, not owing to eclipses, and which several writers have been inclined to attribute to the passage of meteoric streams between the earth and the sun. M. Faye shows that there is not, at present, the shadow of a foundation to support such an opinion.

That the passage of meteor-streams between the earth and the sun has some influence on the earth's temperature, seems more probable, and may be the cause of the aforesaid *cold days*; but more thermometric observations are wanting, before this point can be said to be definitively settled, and I must refer to the papers by M. Ch. St. Claire Deville and M. Faye (in the 'Comptes Rendus' of the Paris Academy, for 1865) for details, as the discussion of this curious question would lead me much too far.

Closely connected with this subject is a curious observation made very recently by M. Heis:—At half-past eight in the evening of the 4th of October last, as this astronomer was observing the Milky Way, he distinctly saw *a dark mass* slowly wending its way along the half-illumined sky, eclipsing the stars in its path. He was enabled to watch this strange visitant from a point situated in right ascension 280°, declination + 21°, to right ascension 291°, declination 18°, when it finally disappeared. And that is all we know about it! Was it a fire-ball, or a non-luminous aerolitic mass, destined to penetrate into the earth's atmosphere at some distance below the horizon? Was it the effect of a large particle of dust in the telescope? Dr. Heis is too much accustomed to observe, to allow himself to be deceived by such an optical illusion.

This is also the place to mention the curious letter addressed to M. Leverrier, last year, by M. Aristide Coumbary, and printed in the 'Comptes Rendus' (29th of May, 1865). The letter is dated from Constantinople, 10th of May, 1865, and is worded as follows:—

"I take this opportunity of communicating to you an observation which I made on the 8th of May, 1865.

"I have for some time been in the habit of directing my telescope to the sun, out of pure curiosity to observe the spots; but, from the commencement of May, I made these observations every day, and I confess that the cause which induced me to direct my telescope more frequently to the sun, and which perhaps is not based upon a plausible reason, is the great changes of temperature, quite *insolite*, which occur at this season in our climate. I do not know how I came to adopt the idea of some astronomers, who suppose the existence of rings of planetary matter round the sun, and, consequently, periods of different degrees of heat emanating from the sun.

"Thus it was, Sir, that on the 8th of May, in the morning, I observed the sun, as usual, about twenty-three minutes past nine, when I perceived a little black point detach itself from a solar spot (see accompanying figure). I was not quite sure about this separation, be-

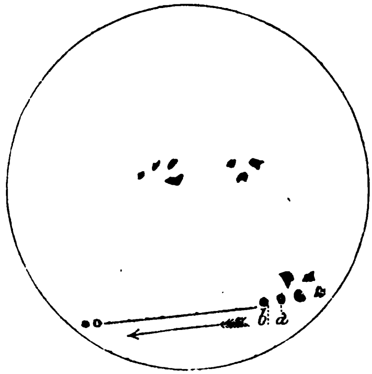



Fig. 23.

Reversed image of the Sun on the 8th of May, 1865; from a drawing by M. Aristide Coumbary, of Constantinople. *a*, first moment of observation, twenty-three minutes past nine; *b*, second observation. Disappearance from the solar disk, twenty minutes past ten. Total interval employed by the circular body in going from *a* out of the disk, forty-eight minutes.

lieving that my eyes were fatigued; I reposed myself for a few instants; on making a new trial, I had no longer any doubt about the displacement; the black point had already attained nearly twice the distance from the solar spot since I had quitted the telescope to repose my sight. This time I distinguished a body nearly round, which moved forward from minute to minute; the ocular glass which I used magnified one hundred and forty times; I changed it for another magnifying two hundred and fifty times. This time I distinguished the black moving body very decidedly, only the second ocular gave a less luminous image, did not depict so well the outline of the body, but rendered its volume more appreciable.

"Towards the end of its route, which lasted about forty-eight minutes, . . . it appeared to take an oval form, and to separate at the centre, as if breaking up into two bodies,—a phenomenon probably owing to fatigued vision, or perhaps to the ocular of the instrument."

It is of course impossible to make any comments here upon this singular observation; the general opinion will probably be, that the body seen by M. Coumbary may be one of the "*interior planets,*" supposed to exist between Mercury and the sun, and which the constant light of this luminary prevents us seeing, unless they happen to cross the disk. But it is perhaps quite as probable, to suppose that M. Coumbary saw a large meteoroid mass, similar to that of M. Heis, or that of Dr. Schmidt, already alluded to in this work.

As we are upon the subject of curious appearances connected with the sun's disk, I cannot pass over the following, which has been consigned by Arago in the 'Annuaire du Bureau des Longitudes,' for the year 1836:—"The astronomer Meissier says that, on the 17th of June, 1779, about mid-day, he saw for about five minutes a *prodigious number of black points* passing across the sun." We have still another, which, if it cannot be attributed to some strange optical illusion, is perhaps one of the most unaccountable phenomena on record. The observation alluded to is related in a letter to the Academy of Sciences at Paris (20th of October, 1820), by M. H. Serres, Prefect of Embrun, and occurred about the termination of the eclipse of the sun, which took place on the 7th of September, 1820.

"The 7th of last month," says M. Serres, "at three-quarters past one o'clock in the afternoon, after having, like every one else, observed the eclipse of the sun, I felt inclined to take a walk in the fields." On going through the little town with this intention, the author remarked several groups of people, who were looking, they said, "*at the stars which were detaching themselves from the sun.*"

"I looked," continues M. Serres, "and I saw, not stars, but globes of fire, whose diameters equalled those of the largest stars, and which were projected in different directions from the superior hemisphere of the sun with an incalculable velocity, and although this velocity appeared to be the same for all, they did not all travel to the same distance. These globes were projected at irregular, but very close intervals. Often several were projected at once, but they were all diverging one from the other. Some shot off in a straight line, and were extinguished in space, others described a parabolic curve, and extinguished themselves also; others, finally, after having proceeded to some distance in a direct line, came back again in the same direction, and appeared to return in their luminous condition into the disk of the sun. The background of this magnificent spectacle was the blue sky slightly tinted with brown."

M. Serres informs us that this spectacle was witnessed by a great number of people; amongst others, may we name particularly M. Thommé, veterinary surgeon, M. Ceyzanne, law-student, and M. Fouré, engineer of the École des Ponts et Chaussées, who certify the exactness of the description of this singular phenomenon given by M. J. H. Serres, the Prefect of Embrun. The attention of the persons just named was called to this phenomenon by some children of the people who were looking at the eclipse.*

An interesting article in the journal 'Cosmos' (vol. i. p. 292, 1852) shows that the "meteoroid masses" seen in the rays of the sun by Mr. Reade, were proved by the later observations of Mr. Dawes to be seeds of various kinds suspended in the air, and carried along by the wind.

Some very curious effects were observed by Mr. Baily during the annular eclipse of the sun, of the 15th of May, 1836, of which an account and figures were forwarded to the Royal Astronomical Society, but I do not think they furnish any explanation of the facts observed by M. Serres. (The drawings in question were reproduced in the 'Illustrated London Almanack' for 1847.)

The ebullition and violent coruscation suddenly observed on the sun's surface, by Mr. W. Hirst, during the ingress of Venus into the solar disk, in 1769, an account of which was communicated to the Royal Society, was evidently an optical illusion, probably caused by fatigued vision.

We must now examine a most extraordinary theory put forth in recent times by our learned friend Professor William Thomson, of Glasgow University, in which the author endeavours, in a most ingenious manner, to account for the constant heat and light of the sun, by sup-

* Compare Ann. de Chimie, vol. xxx., second series, p. 416.

posing a continual fall of meteors upon the sun's surface. This theory is based upon the recent researches into the mechanical equivalent of heat.* Whenever a body in motion comes suddenly to rest, this motion is immediately transformed into its equivalent of heat, which can be accurately calculated.

In this way we have learnt, for instance, that if the planet Jupiter were to fall into the sun, it would evolve, by the shock, as much heat as the sun would give out in 32,240 years. If the rotation of Jupiter suddenly stopped, the heat given out would be equal to the solar emission for 14 years 144 days. Were the sun itself stopped in the same manner, the heat produced would be equivalent to that which the sun evolves during 116 years 6 days, etc.

Professor Thomson's theory has been ably abridged and exhibited in a popular form by Mr. Alexander Herschel (in the 'Intellectual Observer' for March, 1864). The author commences by stating that the sun constantly delivers to the earth in *heat* alone, an energy equal to the one-hundredth part of that force by which it constantly draws the earth into a spiral path about itself. This is but the two-thousand-millionth part of the *total heat* which the sun constantly developes and radiates into space. The production of heat by the sun is constant, and, to all appearances, has been so from the remotest ages of the earth.

If the sun were merely a heated body, it would diminish in temperature and lose its light to a great amount in the course of a very small number of years, or even months. The temperature of the sun does not

* Upon this *equivalent* theory of forces, see my 'Phosphorescence,' pp. 186, 187, *et seq.*

appear to exceed that of the electric arc which we produce in our physical cabinets, *but it remains unchanged.* How is this to be explained? In other words, how does the sun constantly produce the same amount of heat and light? The theory in question replies:—"These two operations (heat and light) may be seen in action together in a fire-ball with a permanent streak of light. . . . A continual repetition of meteors would be required to supply the earth with incessant light from such a source, and such a succession of meteors is therefore supposed to occur upon the surface of the sun. It is calculated that a yearly deposit, sixty-six feet in depth, of solar satellites (meteors) would actually suffice to maintain the present supply of solar light and heat unchanged,—a quantity much too minute to be perceived in less than many thousand years *by angular measurements of the sun's diameter.* The light and heat of meteors upon the earth are confined to the highest strata of the atmosphere. It appears that this is equally the case upon the sun, and that the meteoric particles, from their minuteness, are consumed, and all their elements dissociated at the boundary of the solar atmosphere. Their fiery streaks alone remain. . . . Such streaks are actually seen upon the sun, as straw-like or leaf-like lines, which intersect each other in every conceivable direction. . . . The spots which appear upon the luminous envelope of the sun may arise whenever an aerolitic mass of large dimensions penetrates to the solar surface unconsumed, and with volcanic violence destroys the order of the atmospheric strata where it strikes. The spots are far removed from the solar poles, and therefore near the plane of the ecliptic where the planets have their orbits, but the leaf-like lines are seen over every portion of the sphere of the sun, like fire-balls at the surface of the earth," etc. etc.

The true test for such a theory seems to have escaped Professor Thomson and those who have paid so much attention to his hypothesis. This test consists in the DURATION OF PLANETARY REVOLUTION. If, as Thomson supposes, the sun constantly *gains matter* which it attracts from space, the inevitable consequence is that its attraction for the planets will increase *in direct ratio to the mass* of matter thus gained. Hence it follows necessarily that, supposing his theory true, the duration of planetary revolution must become shorter every year, and this state of things would eventually bring all the planets of the solar system, one by one, to the sun's surface. Now it has been amply proved by François Arago (in the 'Annuaire du Bureau des Longitudes,' for 1834) that the revolution of the earth round the sun has not varied in the slightest degree for a space of 2000 years at least! *

The next question which naturally arises is, whether we possess any evidence of the existence of fire-ball meteors or shooting stars manifesting themselves around,

* The much debated question of the origin and constancy of solar light and heat cannot therefore be solved by Professor Thomson's ingenious theory, which must rather be regarded merely as another illustration of the extent to which the theory of the mechanical equivalent of heat may be applied. The *motion* of the sun itself doubtless engenders both its light and heat; as I have already said in my paper entitled "The Movements of Plants" ('Macmillan's Magazine,' October, 1864) "*motion, like matter, is universal*:" and *if* there exist an *original force*, it is doubtless this. Compare also some admirable papers published within the last few years by Mr. Balfour Stewart ('Proceedings of the Royal Society') and François Arago, 'Astronomie Populaire.' Grove, in his charming work on the 'Correlation of Physical Forces,' admits no *primitive* force.

or in the atmosphere of, other planets besides the earth. As we have already stated, the other planets as well as our earth may have left their *débris*, or their *dust*, along the path in which they circulate; but we have no direct proof of the fact; all we can say is, that those planets which appear from their size, density, etc., to be most similar to the earth, such as Venus and Mars, are probably also visited by shooting stars and fire-ball meteors, and if aerolites fall upon them, we must suppose them to have the same component parts that we should find in the substance of the planet itself. Very recently, M. W. de Fouvielle, in a paper communicated to the journal 'Cosmos' (27th of September, 1865), argues that the ring of the planet Saturn may possibly be composed of meteoroid matter circulating in a tolerably dense mass, and that this ring would appear to an inhabitant of the planet Saturn something similar to what the zodiacal light appears to an inhabitant of the earth. This theory has been objected to by M. Guillemin, the author of the finely illustrated work 'Le Ciel,' who argues (in journal 'Cosmos,' 4th of October, 1865), that Saturn's ring is more probably gaseous matter, conformably with Laplace's celebrated hypothesis of the formation of the universe. Both theories might appear, to a person unaccustomed to observe, equally respectable, but a moment's reflection will suffice to show that Saturn's ring is probably *not* of a meteoroid nature. It can be shown, by means of the little instrument known as the *polariscope*, that the ring of Saturn shines with *borrowed* light; that is, with light which is *reflected*, and therefore, to a certain extent, *polarized*; whereas, if its light were similar to that produced by a fire-ball meteor or a shooting star, having its source within itself, it would show no polarization. The opinion which appears to be more generally accepted is that Saturn's ring is neither solid nor gaseous, but of a *liquid* nature. The American astronomer Benjamin Pierce, in a paper "On the Constitution of Saturn's Ring" (in Gould's Astron. Journ., 1851), agrees with the late Professor Bond, that "the ring consists of a stream, or of streams, of a *fluid* rather denser than water."

Whilst Professor William Thomson, of Glasgow, supposes the sun to be fed with aerolites in order to account for its constant development of light and heat, my ingenious friend M. Boutigny d'Evreux, in his very remarkable work on the spheroidal state of bodies ('Études sur le Corps à l'État sphéroïdal'), published at Paris, 1857, contends that meteors are not shot from the moon, as was formerly supposed, but *from the sun*,—that it is the sun which supplies planetary space with aerolites. Now if we admit the very plausible hypothesis of the Marquis de Laplace, according to which the entire planetary system is derived from the condensation of the sun's atmosphere, naturally the earth and "*its dust*" must have their origin thus accounted for. But M. Boutigny, if I have rightly understood this most obscure portion of his interesting work, believes that the sun, which appears to be in a high state of volcanic activity, throws off aerolites at the present day. This may be perfectly true, but it does not follow that they are the aerolites which reach our globe from time to time.

# CHAPTER XXI.

HAVE METEORS ANY INFLUENCE UPON THE WEATHER?—CAN THE STATE OF THE WEATHER BE PREDICTED BY OBSERVING THE DIRECTIONS OF SHOOTING STARS?—ON THE "HISSING SOUND" OF METEORS IN THE AIR.—OBSERVERS AND COLLECTIONS.—APPENDIX.

ADMIRAL FITZROY, in the second edition of his excellent 'Weather Book' (p. 303), whilst studying the terrible storm known as "The Royal Charter Gale," and considering the premonitory symptoms of storms in general, alludes in a very decided manner to *meteors*. The ship 'Royal Charter' was wrecked on the 26th of October, 1859. Speaking of the preceding summer which had been exceedingly warm and dry, Admiral FitzRoy states that "all over the world, not only in the Arctic but in the Antarctic regions, in Australia, South America, in the West Indies, Bermuda and elsewhere, *auroras* and *meteors* have been unusually prevalent, and they were more remarkable in their features and appearances than had been noticed for many years."

On the Tuesday night (25th of October) preceding the storm, a splended meteor was seen about seven in the evening over many parts of England and Ireland. It is described in the 'Weather Book' (p. 306), in a letter from Sir William Snow Harris, whose son was engaged at the time as civil engineer on the Holyhead Harbour works. It was at seven in the evening (a strong gale blowing from the east, and the night very dark) that Mr. Harris was walking into the town, "and was startled by what appeared to be a *bright ball of fire directly over my head;* the light of it was intense. It pierced through the heavy mass of vapour which obscured the heavens, and illuminated the whole bay and land with the light of day. This meteor lasted from two to three seconds. *Very soon after* this appearance, *the wind increased* to *a hurricane,* and the rain came down like *a deluge.*" The letter also states, that on the 12th, within a fortnight of the storm, *blood-red streams of aurora* were seen.

"This," observes Sir W. Snow Harris, "is worthy of remark, as connecting electrical action with such a storm."

Now it has been long observed, that *auroras* precede what is usually termed "foul weather." But have meteors any connection with these atmospheric changes? In the first place, was the phenomenon, so distinctly described by Mr. Harris, really a meteor, or merely an extensive flash of lightning? On this point there is no doubt; *it was a meteor,* and was also witnessed by Mr. T. T. Carter, whilst at Ballinamar, in Ireland, who gives an elaborate description of it in a letter to Admiral FitzRoy. It appeared first in the direction of the Pleiades, as a star of the first magnitude, and increased rapidly in size. Its light, first of an intense white, soon changed to red, it then burst into about fifteen or sixteen bright emerald-green particles, which disappeared in about two seconds. "*The sky was clear and calm, and there was not the slightest appearance of storm.*" The *sudden increase of wind*, and easterly gale, noticed by Mr. Harris at the time of the meteor's appearance, were therefore purely local, and in no way connected with this phenomenon.

Of late years, the question whether the state of the weather can be predicted by meteoric observations, has been energetically set on foot by M. Coulvier Gravier, in Paris, who asserts, that the direction of the prevailing current of wind can be ascertained by observing the direction of shooting stars, and that these observations enable him to form weather prognostics. Now, from what we have already written in this volume, it will be seen that such a supposition is in the highest degree improbable; and the few writers of eminence who have discussed the subject in France, unanimously condemn it as an illusion on the part of an otherwise indefatigable and accurate observer.

There has been, also, some discussion lately in the 'Times' (and other similarly scientific papers), as to the fact of meteors producing certain *sounds* in the air *before* they explode. The sound alluded to is the "*hissing noise*" so frequently noticed as accompanying the appearance of a large meteor, both by modern observers and more ancient authors. Dr. Burder, of Clifton, called the fact in question on account of the great distance of meteors from the earth's surface, which renders it impossible that any noise can be heard till some time after their apparition, and who attributes the circumstance to the imagination of persons ignorant of the nature of these phenomena. However, we have several very positive facts to the contrary, amongst others, a letter relating to the great meteor seen in various parts of England on the 5th of December, 1863, published in the 'Times,' by Mr. John Williams, Under Sheriff of Beaumaris; *immediately after* the appearance of Dr. Burder's letter. Mr. Williams states, "Both at this place and at Portmadoc, *the hissing sound referred to by some of your informants was distinctly heard.*"*

Fig. 24.

Diagram of the course of a meteor seen in the Province de Namur, October, 1852; from a drawing by M. W. Van Morsel, communinicated to the author, December, 1863.

Mr. Mark Bullen also observes (in a letter to the 'Times,' the 14th of December), that this same meteor was accompanied with "a *whistling sound,*" such as is produced by a "*stone from a sling.*"

A large meteor seen, at Putney, by my sister on the

* Dr. Burder's letter was written on the 17th and published on the 18th; Mr. Williams's letter, dated the 17th, was published on the 19th.

10th of August, 1863, was, she assured me positively, at the time accompanied by a very distinct hissing noise, like that of a rocket.

The cause of this "hissing" or "whistling noise," which *sometimes* accompanies meteors, may perhaps be explained, by assuming that it is due to the compressed air driven before them in their course, and is consequently heard simultaneously with their apparition. I may add that the meteor just alluded to, as observed by my sister, moved with that peculiar spiral motion not unfrequently observed, more especially when the meteor appears to travel directly from the observer, in which case the nucleus appears to perform a series of rapid revolutions upon its path. (See Chapter XIV. and the accompanying diagram.)

In this place we must devote a little space to the names of some of those observers who are, at the present time, paying especial attention to the subject of meteors and aerolites, and, as far as my experience tends, always willing to afford information. The list is probably very incomplete.

*England.*

Mr. Alexander S. Herschel, Collingwood, Hawkhurst, Kent.

Mr. R. P. Greg, Prestwich, near Manchester.

Professor Airy, Astronomer-Royal, Greenwich.

Mr. James Glaisher, Greenwich Observatory.

Professor Baden Powell (Oxford, lately deceased).

Mr. N. S. Maskelyne, Director of the Mineralogical Collection in the British Museum.

Mr. Sidebottam, Manchester.

Professor Hind, London.

Mr. Symons, London. And several others.

*America.*

Professor Denison Olmsted, of Newhaven, United States.

Mr. Newton, *id.*

Mr. Palmer, *id.*

Professor Twining, *id.*

Mr. Shepard, *id.*

M. Andreas Poey, Director of the Observatory of Havana.

*France.*

M. Faye, Member of the Institute, Paris.

M. Coulvier Gravier, Paris.

M. Leverrier, Director of the Observatory of Paris.

M. Petit, Director of the Observatory of Toulouse (lately deceased).

M. Daubrée, Member of the Institute, Director of the Mineralogical Collection at the Jardin des Plantes, Paris.

*Germany.*

Herr Gustav Rose, Director of the Mineralogical Collection, Berlin.

Baron von Reichenbach, Berlin.

Professor Wöhler, Director of the Mineralogical Collection, University of Göttingen.

Dr. Heis, Berlin.

*Bavaria.*

Dr. Buchner, Munich.

*Austria.*

Professor Haidinger, Member of the Imperial Academy of Vienna.

Dr. Hoernes, Director of the Mineralogical Museum, Vienna.

*Belgium.*

M. Quetelet, Director of the Observatory of Brussels.

M. Quetelet fils.

*Copenhagen.*

M. Hansteen, Director of the Observatory.

*Rome.*

Professor Secchi, Director of the Observatory.
Madame Scarpellini.

*Athens.*

Dr. Julius Schmidt (formerly of Bonn), Director of the Observatory.

I have doubtless omitted many names, and I have not repeated here those of several active workers who have analysed aerolites or studied especially their physical properties, as already mentioned.

Mr. R. P. Greg has lately advertised for sale his collection of meteorites. This collection, which comprises 224 separate falls, is stated to be exceedingly rich, and in perfect order; the weight of the whole of the specimens illustrating these 224 falls is nearly 900 ounces avoirdupois, and the price fixed upon the entire collection is £600,—a very reasonable sum, when we consider that fully one-third of the specimens may be said to be purchasable at no price, or never in the market.

The following is, as near as I have been able to ascertain, the actual state of the *public* and *private collections of aerolites;* these collections are increasing rapidly in importance as years roll on :—

1. *Public Collections.*

*London.*—At the British Museum, under the direction of Mr. N. S. Maskelyne (in 1857, 75 specimens); in 1863, 219 *specimens* (30th December, 1863).

*Vienna.*—At the Imperial Museum, under the direction of Professor Haidinger and Herr Hoernes (in 1859, 137 specimens); on the 30th of May, 1863, upwards of 200 *distinct specimens.*

*Paris.*—At the Mineralogical Museum in the Jardin des Plantes, under the direction of Professor Daubrée, (until recently only 86 specimens,) in 1864, 160 *distinct specimens.*

*Berlin.*—At the University, under the direction of Professor Gustav Rose; April, 1863, 153 *specimens.*

*Göttingen.*—At the University, under the superintendence of Professor Wöhler; in April, 1863, 137 *specimens.*

2. *Private Collections.*

*Manchester.*—At Prestwich, near Manchester, the collection of R. P. Greg, Esq.; 224 *distinct specimens* (in December, 1865).

*United States of America.*—Mr. Shepard's collection, 151 *specimens.*

*Berlin.*—The collection of Baron von Reichenbach, 176 to 200 *specimens.*

It will be observed, that of all these collections that of Paris is increasing the most rapidly; the cause of this lies in the untiring efforts of Professor Daubrée, who, for the last few years, since his election to the chair of Geology, in the Paris Museum, is endeavouring to make this collection the finest and most complete in world.

At present, however, the richest and finest collection is, by far, that at the British Museum; and there is no doubt that under the able management of Professor Nevil Story Maskelyne, this collection will never be eclipsed by any other.

The Vienna collection is also exceedingly rich; it was for some years the finest in the world, and the number of its specimens is increasing rapidly.

Fig. 26.

Mass of meteoric iron, weighing 1200 pounds, discovered at Caille, near Grasse, in the Département du Var, France; drawn from the specimen in the Museum of the Jardin des Plantes.

# APPENDIX.

The papers announce the fall of two aerolites which occurred on the 7th of September, 1865, within half a mile of each other, at Muddoor, in India. It was in the *daytime*, and three loud reports like the explosion of shells in the air were heard by many people. Three natives, immediately after the reports, saw the fall of the stones, which raised a great quantity of dust. They were at first frightened, but called others to their assistance, and dug out the stones. Their depositions were afterwards taken. The first of them, named Kenda, was very much frightened; he "did not go close to it, because he thought some calamity had fallen there from the heavens." The two others made a similar declaration. A large number of persons, including the police, were brought by these natives to the spot, and the two stones, on being dug out in a broken state, were found to be identical in appearance. The resident Alimidar took down their statements in writing, and sent the whole at once to Mr. L. B. Bowring, Commissioner for the province of Mysore. These specimens will doubtless soon be seen in the collection at the British Museum.

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In a recent volume of the "Annuaire" of the journal 'Cosmos' is a short *résumé*, from the pen of the Abbé Moigno, of M. Coulvier Gravier's views on aerolites, bolides, and shooting stars, The account is mainly from M. Coulvier Gravier's larger work.

'Sur les Étoiles filantes.' According to this observer (whose views on this subject differ in many respects from those entertained by others), the mean density of meteorites is 3 (water being 1), and 3 represents the density of the bodies which circulate in planetary space between Mars (whose density is 5·2) and Jupiter (whose density is 1·4). Aerolites would therefore appear to form part of the group of small planets; they may be small planets, broken up, attracted out of their original orbits, etc. According to this hypothesis, the radius of the orbit of aerolites would be greater than that of the earth, therefore the earth would meet them more probably at its aphelion than at its perihelion; now, according to this author, *June* and *July* are precisely the months in which most aerolites have fallen upon the earth. We find, effectively, on Professor Maskelyne's list of 138 falls, 28 in June and 10 in May, or for these three aphelic months, taken together, 38 falls. The predominance of these three months over the others is therefore not so great. For the months of October, November, and December, we find on this same list, out of 138 falls, 34 falls for these perihelic months. This only tends to show with what caution the views of M. Coulvier Gravier and the Abbé Moigno must be received.

*Bolides* are looked upon by these authors as having cometary orbits, having their perihelia near the orbit of Mercury; hence the earth would meet with them most frequently on its way from the aphelion to the perihelion, or from July to January—which happens to be the case.

*Shooting stars*, according to the same author, appear to come from beyond the atmosphere, in a direction precisely opposite to the translatory motion of the earth in its orbit. The mean number of falling stars in a night (taking all nights together) is, according to M. Coulvier Gravier, ten per hour, or about 90,000 (87,600) per annum. They appear to be drawn from all directions towards an unknown central point, situated at 22° 30′ north-by-east; their mean direction for each hour changes and progresses regularly 10° per hour from east to west. Shooting stars, according to this author, radiate from four principal centres—Perseus, the Lion, Cassiopeia, and the Dragon's head, Perseus being the most abundant centre (radiant point). English observers have recognized a considerable number of other radiant points, as we have seen previously. Speaking of periodic streams, the same author observes, that these extraordinary apparitions are explained by supposing the existence of one, or several, cloud rings of cosmical matter circulating round the sun in an orbit inclined about 7° on the ecliptic. Periodic streams are sometimes only visible to a restricted portion of the earth's surface; that of November, 1837, very brilliant in England, was not noticed in Prussia, where only a few falling stars were seen at the same time. M. Coulvier Gravier explains this anomaly by supposing that the nebulous ring is not equally rich in its different parts; he even supposes it may be, at some places, quite empty, whilst its densest portions, when interposed between the sun and the earth, have probably caused those obscurations of the solar disk which we have already alluded to. These obscurations have happened principally, says this author, on the 7th of February and 12th of May (see *ante*), two dates which are at six months' distance from the 10th of August and 13th of November. So that the denser portions of the meteoroid ring which produce the periodic streams of August and November at opposition, produces solar obscurations at conjunction.

I shall make no further remarks on these views; they may be quite as reasonable as those put forward by many other authors, and already discussed in the present volume.

---

Since Baron Reichenbach attempted to collect some of the dust of falling stars, upon the barren and elevated hilltops of central Germany, I have myself, accidentally, and whilst pursuing quite a different subject, discovered a means whereby some of this meteoric dust may be collected at certain periods of the year, after the great star-showers of August and November. I have frequently exposed to the wind a sheet of glass covered over with some transparent mucilaginous substance, to collect the various organized particles which float in the air, and which can thus be studied under the microscope. This kind of experiment has given me some curious results in Brussels, Paris, and London. At Brussels and Paris I have caught in this manner, when the wind was in the proper direction, the hairs of several alpine plants, besides numerous animalcules, grains of quartz, etc. Latterly I have used for this experiment a small sheet of glass covered with glycerine, and exposed to strong southerly gales blowing at the rate of about forty miles an hour. On examining the slides under the microscope, we find that the atmosphere will yield in this manner a great number of curious objects which, of course, escape the usual methods of chemical analysis. I have found that when the glass, covered with pure glycerine, is exposed to a strong wind late in November, it receives a certain number of *black angular particles*, some three or four of which may be thus collected in the space of a couple of hours. The experiment being made far in the country, away from the "smuts" of a town, the black particles show themselves all the same. They are, however, not soot or charcoal; they can be dissolved in strong hydrochloric acid, and produce yellow chloride of *iron* upon the glass plate. This is all I know of them at present; it is not improbable that these dark particles may be the elements of the meteoric dust left in the air by the many thousand falling stars, which burn completely away in their rapid passage through the atmosphere. Although I have made this experiment at various periods of the year and in different countries, it is only in the winter months that the black particles, giving with hydrochloric acid chloride of *iron*, have been met with.

---

The late and much regretted Dr. Forchammer, Professor of Chemistry in Copenhagen, has described a meteoric iron discovered by Rinck in the possession of the Esquimaux at Niakoruak, lat. 69° 25′, by whom it had been found, a short distance from their hut, on a stony flat, through which the river Annorritok flows into the sea. It weighed twenty-one pounds, and had a specific gravity of 7·00. It was so hard that it could be neither filed nor sawed, but was very brittle. (Generally meteoric iron is very malleable.) Its fracture was granular. It took a high polish, and showed beautiful Widmannstäten figures when acted on by nitric acid. By treatment with acid its evolves sulphuretted hydrogen, and hydrogen of a disagreeable odour, exactly like inferior cast iron.

At first iron alone is dissolved, and a black matter consisting of minute crystals is left behind, which eventually dissolves, and a black powder, which proved to be *carbon*, floats through the liquid; while in place of the fragments of iron a grey porous mass, amounting to one or two per cent. of the stone, is left. It contains—

| | |
|---|---|
| Iron | 93·39 |
| Nickel | 1·56 |
| Cobalt | 0·25 |
| Copper | 0·45 |
| Sulphur | 0·67 |
| Phosphorus | 0·18 |
| Carbon | 1·69 |
| Silicium | 0·38 |
| | 98.57 |

Besides these were found metals of the alumina group (oxides soluble in caustic potash), of the zirconia group (oxides insoluble in potash, but precipitated from their salts by sulphate of potash), and of the yttria group (oxides insoluble in potash, soluble in carbonate of ammonia, and not precipitated by sulphate of potash). The two latter groups have not been previously found in meteorites; they form the principal part of the undissolved grey porous mass. The crystalline grains, which are less soluble than the rest of the mass, appear to be composed of a carburet of iron, $Fe_2C$, containing 9·66 of carbon, and having a specific gravity = 7·17.

This meteoric iron belongs to a very rare variety, and contains so large a quantity of carbon that it might be called, according to the author, meteoric cast iron. That found in Greenland by Parry, as well as another specimen, mentioned by the author of this paper, were perfectly malleable. (Poggendorff's 'Annalen, and the 'Chemist,' 1855).

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Dr. Böttger gives the following as his method of etching meteoric iron, so as to render their internal structure visible, and produce the curious Widmannstäten figures, to which we have more than once alluded.

Nitric acid of 1·2 specific gravity is diluted with an equal volume of water, and the stone or iron, having been previously cut and polished, is placed in the solution. The sides and parts not required to be acted upon are coated with a solution of asphalte in benzol. To facilitate the action of the acid, the face of the stone is touched lightly from time to time with a camel-hair pencil, and after a lapse of five or six minutes the stone is taken out of the acid, carefully washed, first in water, then in carbonate of soda, to remove every trace of acid, then washed and dried; the asphalte is dissolved by turpentine, and the surface acted upon by the acid is coated with a solution of paraffine in benzol, which effectually preserves it from rust, and forms upon this surface a perfectly transparent varnish.

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I am glad to find that the November fall for 1865 has been carefully observed by Mr. Knott, who communicated his observations to the Literary and Philosophical Society of Manchester, on December 12th. Between twelve and one A.M. on November the 12th, the author counted thirty-nine meteors; during the next fifty-five minutes he counted sixty-one meteors; from twenty-five minutes past two A.M., to five minutes past three, when he ceased observing, fifty-five meteors were counted. During the last forty minutes, it was clearly noticed that the *radiant point* of these meteors was in the constellation Leo. The paths of a few of the shooting stars suggested a second radiant point near $\beta$ Tauri.

On this occasion, the author remarked that these periodic meteors have a tendency to occur in groups of four or five, appearing in rapid succession, then followed by a lull, during which none were seen. I have myself observed the same phenomenon in August, 1864, and I have even seen two shooting stars occur simultaneously in the same region of the sky, and follow different directions, so as to appear to the observer like one meteor, which suddenly changes its course and shoots away at right angles to its first direction. During this August period, I made several sketches of these groups, but they have, unfortunately, been mislaid.

Mr. Alexander Herschel, who seems to have devoted himself specially to the study of detonating meteors, has recently published, in the pages of the 'Intellectual Observer,'* another interesting paper, which is an important addition to those, by the same author, which I have already mentioned. The object of this paper is, to call attention to the dates 9th–11th of February and 19th–21st of November, as deserving of future study, with the special view of determining the direction of detonating meteors. At present *the frequent return of detonating fire-balls on these dates* appears to indicate the fact "that these bodies, like the acknowledged star showers of August and November, revolve in fixed orbits round the sun."

---

The enormous mass of meteoric iron now in the British Museum, where it arrived from Australia a short time ago, has the following history attached to it †:—In 1861, a great mass of meteoric iron was discovered at Cranbourne, near Melbourne. It weighed about 2,800 lbs., and was transported to the British Museum. When the author of this work visited this national collection a few weeks ago, in order to make a new observation of this enormous meteorite, the largest known, it was nowhere to be seen,—in fact, it was on its way back to Australia. Its *better half* had been discovered in the same locality, and had been generously exchanged by the authorities at Melbourne for the *smaller* mass in the British Museum. After the first mass had been extracted from the earth, and dispatched to England, it was found, effectively, that a still larger mass remained interred. In course of time it was extracted also, and proved, doubtless, to be a larger portion of an immense meteoric mass, which had broken during its fall, and of which the specimen sent to the British Museum was the other portion.

How much the new fragment weighs I am not aware; it is however safe in the Museum, and will soon be exhibited to the public. It is the largest meteoric mass ever discovered.

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* Int. Obs., March, 1866. † 'Cosmos,' Jan. 24, 1866.

Some of the most important results obtained in Professor Daubrée's recent researches into the connections between aerolites and certain eruptive rocks of our globe may be stated in a few words. He finds that the *iron* smelted directly out of some of our volcanic and eruptive rocks gives the same Widmannstäten figures that meteoric iron does, which our ordinary iron does not. When serpentine and olivine (or peridot) are treated in this manner (*i.e.* smelted like ordinary iron ores), they yield a button of iron, which contains a notable quantity of *nickel* and some *chrome*. None of the rocks which form the stratified crust of the earth, nor even granite, gneiss, etc., are met with in aerolites. The rocks which are found to resemble the latter in their chemical composition are those which come up from the *depths* of the earth,—in other terms, the more recently erupted rocks.

Daubrée has succeeded in proving that the relation between the eruptive and volcanic rocks of our globe and aerolites is much greater than was hitherto supposed, and his interesting papers in the 'Comptes Rendus' (29th of January, 19th of February, and 19th of March, 1866) tend to confirm most completely our own notion, as set forth in these pages, that aerolitic swarms are the fragmentary *dust* of the earth itself travelling in space like our globe, and in orbits similar to that of the latter.

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The remarkable meteoric stone which fell at Dhurmsala, spoken of in Chapter IX. of the present work, has just been submitted to a most detailed chemical analysis by Dr. Samuel Haughton, of Trinity College, Dublin (Proceed. of the Royal Society, 1866, no. 85). The author confirms the statement that these stones were intensely cold at the time of their fall. "The cold of the fragments that fell was so intense as to benumb the hands of the coolies who picked them up, but who were obliged, in consequence of their coldness, instantly to drop them." The specific gravity of this remarkable aerolite is 3·399. The stone is grey, close-grained, and splintery in fracture; it presents fewer specks of metallic iron and magnetic pyrites than usual, and was coated with the ordinary black pellicle on its outer side. The general composition may be given thus:—

| | | |
|---|---|---|
| Nickel iron | 8·42 | { Iron . 6·88<br>Nickel. 1·54 |
| Protosulphuret of iron | 5·61 | |
| Chrome iron | 4·16 | |
| Olivine | 47·67 | |
| Insoluble silicate | 34·14 | |
| | 100·00 | |

Dr. Haughton also adds, for the sake of comparison, the results of his analysis of a meteoric stone which fell at Dundrum, county Tipperary, at seven P.M. on the 12th of August, 1865, of which fall I have seen no account. It contains:—

| | |
|---|---|
| Iron | 19·57 |
| Nickel | 1·03 |
| Sulphide of iron | 4·05 |
| Chrome iron | 1·50 |
| Olivine | 33·08 |
| Insoluble silicate | 40·77 |
| | 100·00 |

The presence of schreibersite does not appear to have been sought for in these analyses.

---

Some aerolites very similar to the above, weighing two, four, and eight pounds, fell at St. Mesmin (Aube), on the 30th of May, 1866, with the usual meteoric phenomena. The fall occurred about a quarter to four o'clock in the morning. It has been most minutely described by Professor Daubrée ('Comptes Rendus,' 18th of June, 1866), and the stones analysed by Pisani (*idem*). They contain about 5·6 per cent. of nickeliferous iron, 40·6 of insoluble silicates, etc., and 59·4 parts soluble in acid. Their specific gravity is 3·426. I must refer to these two papers for many interesting details.

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The following is the passage of Plutarch concerning the fall of the meteorite at Ægos Potamos, 465 B.C.:—

"There were those who said that the stars of Castor and

Pollux appeared on each side of the helm of Lysander's ship when he set out at first against the Athenians. Others thought that a stone which, in the common opinion of man, fell from heaven, was a prediction of this overthrow. It fell at Ægos Potamos, and was of prodigious size. The people of the Chersonesus hold it in great veneration, and show it to this day. It is said that Anaxagoras had foretold that one of those bodies which are fixed in the vault of heaven would one day be loosened by some shock or convulsion of the entire machine, and be precipitated to the earth. . . . But there is another more probable opinion which professes that falling stars are not emanations or detached parts of the elementary fire, . . . nor yet a quantity of air bursting out from some compression, and kindling in the upper regions, *but that they are really heavenly bodies which from some relaxation of the rapidity of their motion, or by some irregular concussion, get loosened and fall,* not so much upon the inhabitable part of the globe as into the ocean, which is the reason why their substance is so seldom seen.

"Damachus, however, in his treatise concerning religion, confirms the opinion of Anaxagoras. He relates, [that for seventy-five days together] before that stone fell there was seen in the heavens a large body of fire, like an inflamed cloud, not fixed to one place, but carried this way and that with a broken and irregular motion; and that by its violent agitation several fiery fragments were forced from it, which were impelled in various directions, and darted with the rapidity and brilliancy of so many falling stars. After this body was fallen in the Chersonesus, and the inhabitants, recovered from their terror, assembled to see it, they could find no inflammable matter, or the least sign of fire; but a real stone, which though large, was nothing in comparison to the size of the fiery globe they had seen in the heavens, but appeared only as a bit crumbled from it."

There is some mistake about the "seventy-five days," otherwise this description coincides very remarkably with the phenomena the fall of such a stone may be supposed to have produced.

---

At a recent meeting of the Royal Institution, Mr. Alexander S. Herschel gave a discourse on the shooting stars of 1865 and

1866. He also refers to the night of the 13th of November 1866, as that on which a maximum of these meteors may be expected. Three hundred observations recently made by him in England on the height of shooting stars, coincide very exactly with those lately made by Mr. H. Newton in North America. In submitting the train of certain fire-ball meteors to the test of spectrum analysis he discovered in it the presence of sodium vapour.

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## THE STAR-SHOWER OF 13-14TH OF NOVEMBER, 1866.

Whilst correcting the last proof-sheets of the present work, it has been my good fortune to witness, in all its splendour, the realization of the conjecture set forth on pp. 158 and 181. The prediction that a large fall (or swarm) of meteors might be expected to occur from the 11th to the 14th of November, 1866, has been realized, and a more extraordinary sight it was not possible to witness. The state of the weather prevented any observation on the night of the 12th. On the 13th I began to observe early, knowing that the larger meteors generally show themselves in the *evening*, and at twenty minutes past nine saw the first meteor. It rose *directly from the horizon*, from the direction of the constellation Leo, which had not yet risen; it mounted at first rather slowly, like a rocket,—which indeed I took it to be,—but it rose still higher and higher, and shot away rapidly and silently to the other side of the heavens, passing directly over my head. It was a good augur of what was to come that night; for this large shooting star, the finest I ever saw, was evidently an outlier of the November group, issuing from the constellation Leo. It was also seen from Hyde Park by Mr. Ch. Harding, who saw it describe an arc of nearly 180°. Its head appeared copper-red, and its long train, which lasted only a second or two, emerald green. Shortly afterwards I saw one or two others, not quite so fine; but, before I had finished my observations, I saw meteors at the rate of *considerably more than* 2500 *per hour!* In fact, from half-past twelve to half-past one *it was impossible to count them, though two of us endea-*

*voured to do so.* It was easy to perceive, whilst observing this magnificent spectacle, that the meteors all *radiated* from the direction of the constellation Leo. Out of the *many thousands* of falling stars I must have witnessed that night, five only did not come from that direction. In the astronomical world the night of the 13-14th of November, 1866, will remain for ever a period of extraordinary interest, confirming directly the fact conjectured by Humboldt and others, that the *November period* of shooting stars attains its *maximum* every thirty-three years.

Here are the observations which I made upon the night in question:—From twenty minutes past nine to five minutes past ten I saw two meteors only; from five minutes past ten to five minutes past eleven were seen three meteors. I then began to observe methodically, and noted the number each quarter of an hour:—

| | h. m. | | h. m. | | | |
|---|---|---|---|---|---|---|
| From | 11 0 | to | 11 15 | were seen | 14 meteors. | |
| „ | 11 15 | „ | 11 30 | „ | 13 „ | } weather |
| „ | 11 30 | „ | 11 45 | „ | 14 „ | } cloudy. |
| „ | 11 45 | „ | 12 0 | „ | 24 „ | |
| „ | 12 0 | „ | 12 15 | „ | 58 „ | |
| „ | 12 15 | „ | 12 30 | „ | 120 „ | |
| „ | 12 30 | „ | 1 0 | impossible to count them. | | |
| „ | 1 0 | „ | 1 10 | (in ten minutes) | 425 meteors. | |
| At | 1 40 | the number was evidently diminished. | | | | |
| From | 1 45 | to | 2 0 | were seen | 198 meteors. | |

A short time *after* the period of *maximum*, the stars fell at the rate of 2550 per hour; from half-past twelve to half-past one there may have been some 6000 or 7000 meteors in one hour. Professor G. J. Symons, who observed from another part of London, estimated, at twelve minutes past one A.M., one hundred meteors per *minute* for the entire heavens.

His observations, noted every five minutes, are as follows:—

| | h. m. | | h. m. | | |
|---|---|---|---|---|---|
| From | 11 45 | to | 11 50 | were seen | 17 meteors. |
| „ | 12 0 | „ | 12 5 | „ | 21 „ |
| „ | 12 15 | „ | 12 20 | „ | 41 „ |
| „ | 12 30 | „ | 12 35 | „ | 83 „ |
| „ | 12 45 | „ | 12 50 | „ | 87 „ |
| „ | 1 0 | „ | 1 5 | „ | 264 „ |

| | h. m. | | h. m. | | | |
|---|---|---|---|---|---|---|
| From | 1 15 | to | 1 20 | were seen | 276 | meteors. |
| „ | 1 30 | „ | 1 35 | „ | 141 | „ |
| „ | 1 45 | „ | 1 50 | „ | 60 | „ |
| „ | 2 0 | „ | 2 5 | „ | 48 | „ |
| „ | 2 15 | „ | 2 20 | „ | 25 | „ |
| „ | 2 30 | „ | 2 35 | „ | 25 | „ |
| „ | 2 45 | „ | 2 50 | „ | 20 | „ |
| „ | 3 0 | „ | 3 5 | „ | 26 | „ |
| „ | 3 15 | „ | 3 20 | „ | 20 | „ |
| „ | 3 30 | „ | 3 35 | „ | 18 | „ |
| „ | 3 45 | „ | 3 50 | „ | 12 | „ |
| „ | 4 0 | „ | 4 5 | „ | 16 | „ |
| „ | 4 15 | „ | 4 20 | „ | 12 | „ |
| „ | 4 30 | „ | 4 35 | „ | 8 | „ |
| „ | 4 45 | „ | 4 50 | „ | 4 | „ |

The newspapers of the 15th of November are full of accounts of this extraordinary meteoric stream; and the results of various observers who noted the number of falling stars in a given time, correspond very closely with the above. It will be remarked that the maximum intensity of this brilliant manifestation came on very rapidly, and diminished as rapidly. All observers agree that the *greatest intensity*, from whatever locality in England it was witnessed, came on and decreased between twelve and two o'clock. A considerable number of the meteors were very large and brilliant, but the finest, beyond doubt, was that I witnessed as early as twenty minutes past nine. The head or nucleus of most of them was red or yellowish-red, and the trains light emerald green. In the immediate neighbourhood of the *radiant point* (between $\gamma$ and $\mu$ Leonis) they showed themselves as short flashes or mere points of fire. In some instances the head shone with an intense white light, and appeared perfectly globular.

I must now allude to a phenomenon which accompanied this wonderful meteoric swarm, and appears to have been noticed several times in years gone by. At various intervals I observed sudden flashes of light, which I attributed to lightning from a storm below the northern horizon; but I think I have proof that there was no storm at the time, for observers both at Coventry and Northampton remarked the same flashes. The first flash occurred at twenty minutes past nine, two others at five minutes past ten, another at thirty minutes past ten, one at ten minutes to eleven, and one at one o'clock. Moreover, from Putney peculiar electric (?) radiations were seen at intervals in the northern sky. Professor Symons says, "No lightning was seen from Camden Town, unless it was at thirty-five minutes past twelve, when two flashes of light were seen, and supposed to be from meteors in the north." Professor Hind observed several flashes of lightning (?); at fifty-four minutes past three he saw a very brilliant flash of a deep orange colour, which emanated from below the radiant point in Leo. The horizon in that quarter was occupied by a pale glow, resembling what has often been remarked during an *aurora borealis*. At Coventry several flashes of light, supposed to be lightning, were seen by Mr. W. Tyler and others, precisely as at London; they resembled more the bursting of a bomb than ordinary lightning. Dr. Burder, of Clifton, remarked, during the earlier part of the night, a rather strong diffused light, "no doubt of an *auroral* character," prevailing in the north; the same was seen by me, and attributed to the radiations from the city of London. All this leads me to believe that these brilliant meteor-streams electrify the higher regions of the atmosphere, and produce phenomena analogous to the *aurora borealis*.

At Greenwich Observatory, the number of meteors observed per hour, during this remarkable stream, were as follows:—

| | |
|---|---|
| From 9 to 10 | 10 meteors. |
| „ 10 „ 11 | 15 „ |
| „ 11 „ 12 | 168 „ |
| „ 12 „ 1 | 2032 „ |
| „ 1 „ 2 | 4860 „ |
| „ 2 „ 3 | 832 „ |
| „ 3 „ 4 | 528 „ |
| „ 4 „ 5 | 40 „ |

The observations were made, under the direction of Mr. James Glaisher, by several persons well accustomed to work of this kind.—It has been noticed that just before sunrise on the 14th the Zodiacal light was more than usually brilliant.

J. E. Taylor and Co., Printers, Little Queen Street, Lincoln's Inn Fields.