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A VIEW

Of the Theories which have been proposed, to explain  
The Origin of Meteoric Stones.

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From the earliest periods of history, there have been numerous reports of falling bodies from the heavens. But, till within a very few years, the subject has been considered, as belonging, rather to fiction and poetry, than to sober philosophy. Men of science, aware, it would seem, of the difficulty of assigning a plausible reason for the descent of masses of stone from the atmosphere, have chosen to intimate, by a significant silence, their disbelief of the accounts which had been given of their fall. But the subject has lately intruded itself of their notice, in a way that has left them without an apology for refusing, any longer, to take it into consideration. A body of evidence has been accumulated, which it would require more ingenuity to explain away, than to account for the phenomena. They have accordingly come forward, at last, with a very liberal supply of hypotheses. These have been proposed, by different persons, and on various occasions; and are scattered among the transactions of philosophical societies, periodical publications, and fugitive papers. It may be of some service, to collect them into one view; and to compare them with each other, and with the facts which they are intended to explain.

Before a direct examination of the merits of these theories, it will be important to recollect, that the falling of stones is frequently, if not invariably, connected with another phenomenon, the passage through the air of one of those large luminous meteors, which occasionally make their appearance in our atmosphere. When the stones have fallen in the *day* time, the meteor has not always been observed: probably because its light was not sufficiently strong to draw the attention of persons abroad, to that part of the heavens in which it was moving. But, even in this case, the same kind of *report* has been heard, as that which usually follows the explosion of a meteor. In many instances, the luminous body has been seen to come forward to the zenith, and apparently to burst; and, immediately after, the stones have fallen, with a whizzing noise, to the ground.

Meteors of this kind are seen, in some parts of the world, almost every year. They appear moving through the heavens, like balls of fire, or red hot iron. Their apparent diameter is sometimes as large as the moon. From the main body, frequently extends a flame or train. Streams and sparkles of fire seem to shoot out, on every side. Just before

their disappearance, there is a violent explosion; by which pieces often appear to be detached, and thrown to the ground.

The same meteor is seen over a great extent of country; in some instances, a hundred miles in breadth, and five hundred in length. Bodies seen from such distant places, at the same time, must have a great elevation. From various calculations, it appears, that, during the time in which they are visible, their perpendicular altitude is generally from twenty to a hundred miles. Their diameter is, in some cases, estimated to be at least a half a mile.

Their velocity is astonishingly great. Though they are rarely visible, for more than a minute; yet they are seen to traverse many degrees in the heavens. Their rate of motion cannot, according to calculation, be generally less than three hundred miles in a minute.

It is not, in every case, known that these bodies project anything to the earth. It is probable, however, that stones do, in many instances, fall from them without being noticed. For, as they bury themselves a considerable depth in the ground; there could be little chance of their being discovered, unless they were either seen or heard to fall. But the instances in which they have been actually observed to descend through the air, immediately after the explosion, are sufficiently numerous to establish the point, that the stones proceed from the meteor. The two phenomena, therefore, are really but one event: and no hypothesis can be admitted as a satisfactory explanation of the one, which does not, at the same time, account for the other. Whether any of the various conjectures which have been proposed for this purpose are founded in truth, must be determined by making a comparison between the leading features of each, and the facts to which they are intended to be applied.

1. One hypothesis is this; that the materials of which the meteoric stones are composed, are raised into the air in the state of exhalations or gases – that, in the upper regions of the atmosphere, they are occasionally collected in great abundance – that, some of them being inflammable, a combustion takes place – and, that the particles of the whole, by their mutual attractions, rush together, and form a mass, which descends by its weight, to the ground.

To this supposition there are several important objections. In the first place, the principal substances of which these bodies are composed, are never known to be raised in vapour. The ingredients are iron, silex, magnesia, nickel and sulphur. Several of these cannot be evaporated, even by the powerful heat of a furnace. In what way then can they be carried up, fifty or a hundred miles, from the surface of the earth?

But, supposing the materials, by some unknown process, and contrary to all our experience, to be carried into the air, and the bodies to be formed there; what is there in the atmosphere, which could give them their rapid horizontal velocity? A solid substance elevated to a great height, and left to itself, would *descend* very rapidly. But the motion of a meteor is not, like that of a falling body, perpendicular to the horizon, but almost parallel. Its velocity is such as could not be produced by the atmosphere. The air will not communicate, to a body floating in it, a motion more rapid than its own. The progress of the most violent wind is not more than two or three miles in a minute. But the meteor moves several hundred. The velocity of sound is less than twelve hundred feet in a second: that of a meteor, more than twenty thousand. The greatest force of gunpowder, will throw a cannon ball but a very few miles. A meteor is often seen to move several

hundred. Is it not incredible, that a power sufficient to produce such a motion should reside in the atmosphere?

There is still another very weighty objection, to the supposition that these substances are formed in the air. It cannot be true, as the theory would imply, that the body of the meteor falls to the ground. The pieces which come down are only fragments, detached from a much larger mass. This is evident, from the size of the meteors. They are calculated to be several hundred feet in diameter. One which was seen in England and France in 1783, was computed to be almost two miles in circumference. From the various accounts which have been given of that which lately exploded over Fairfield County, in this state, it is evident, that it must have been many thousand times larger than the amount of all the stones which have been found. The whole that has been collected, would not form a sphere two feet in diameter. This, at the distance of fifty miles, would subtend an angle of less than two seconds of a degree: and, therefore, if seen at all, would appear like a fixed star, a mere visible point, too small to be measured by the nicest instruments. But the meteor from which these stones proceeded, had a very considerable apparent diameter, to those who saw it even at greater distances.\* It is not pretended that the dimensions can be ascertain-

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\*NOTE.....It was seen at Wenham, in Massachusetts, 150 miles from the nearest part of its path.

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ed with any great degree of accuracy. The appearance is so sudden and unexpected, that no opportunity is afforded of measuring the diameter with an instrument. Some exaggeration is to be expected, from the novelty and splendour of the object, and the surprize of the observer. And it is possible that the apparent dimensions of the meteor may be enlarged, by the flame or glare of light, with which it is sometimes accompanied. But, after making ample allowances on all these accounts, the body will still remain vastly larger than any which has been known to fall to the earth. It cannot be the fact that the luminous object is *principally* flame or vapour. If this were the case, it could not preserve a regular globular figure while moving through the atmosphere with a velocity twenty times as great as that of sound. It would be immediately dissipated. The great body of the meteor must be a solid compact substance, capable of sustaining the resistance of the air. Its magnitude is such, as to illuminate, at once, a region of over one or two hundred miles in extent. It is inconceivable, that a body only two or three feet in diameter, however luminous, should attract, at the same moment, the gaze of a whole country; and appear, to the distant spectators, one third, one half, or three fourths as large as the moon. The real diameter of the meteor, according to the lowest computation, must be some hundreds of feet. No such body has ever come to the ground.

Of the meteor which was lately seen in this state, the part that has gone from us, is many thousands of times as great as the sum of all the pieces which have been discovered. After throwing off a few hundred weight from its surface, it must have held on its course, and either revolved round the earth, or gone off to the distant regions of the heavens. It must require a strong faith to believe that the atmosphere, even if furnished with materials, could produce *such* a body, and then give it a velocity sufficient to carry it beyond the circumference of the earth.

2. A second hypothesis is, that the meteoric stones are masses of matter thrown from volcanoes. But this is embarrassed with difficulties as great as the one which has already been examined. In the first place, the substances which are known to be thrown from volcanoes, are all of a different kind from these stones. No such bodies are found in their craters, or in the neighborhood where the lava has fallen. It may therefore be concluded that none such have ever proceeded from them.

In the next place, the stones have fallen at the distance of several hundreds or thousands of miles from any volcano. It is next to impossible that they should be carried thus far, by any force which could be applied to them near the surface of the earth. The resistance of the air is so great, that it will not suffer the motion of a body in the lower regions of the atmosphere, to exceed a certain limited rate. This has been ascertained by the numerous experiments which have been made, for the purpose of improving the theory of gunnery. It is found that if the greatest possible velocity be given to a cannon ball, the air will almost immediately reduce it to about eleven or twelve hundred feet in a second. A larger body would indeed be retarded in a less degree. Still, the resistance would be such as to bring it soon to the ground. It requires an initial velocity, greater than that of sound, to carry a cannon ball only three or four miles. Is it not then incredible, that a body a quarter of a mile in diameter, should be thrown from a volcano, with a force sufficient to carry it hundreds or thousands of miles; and that, after having gone this distance through the atmosphere, it should still retain a velocity greater than that, with which a shot issues from the mouth of a cannon? But what decides the point, is, that the meteor, after all, does not fall to the ground. It moves on, in a curve, which could not be described by a body, that had commenced its motion at the surface of the earth.

Mr. King has varied this theory,\* to accomodate it to the particular circumstances of the fall of stones at Sienna in Tuscany. He supposes that these substances were thrown from a volcano, not in solid masses, but in the state of dust or ashes. Sienna is about two hundred miles from Vesuvius. The shower of stones was the

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\*See "Remarks concerning Stones said to have fallen from the clouds. By Edward King, Esq. F. R. S. London, 1796."

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next day after a great eruption from that well known volcano. Though it is scarcely credible that *solid bodies* could be projected to this distance; yet it is thought not to be impossible that *pulverized* substances should be wafted thus far in the air. Mr. King supposes that a vast quantity of ashes, composed of particles of iron, sulphur, and other ingredients, was thrown from Vesuvius to a prodigious height – that they there formed a cloud, and floated to the region of the atmosphere over Sienna – that when they began to descend, they became so much condensed, as to take fire, and produce numerous explosions – that the pyritical, metallic and argillaceous particles were melted – and that when cooled again, they were consolidated into the masses which were seen to fall to the ground. It is unnecessary to enter into a minute examination of this theory; as it is framed to suit the peculiar circumstances of the fall of stones at Sienna, and is applicable to no other case. It may be sufficient to observe, that, excepting merely the difficulty of getting the materials into the air, it is liable to all the objections which have been stated to the supposition, that the meteoric bodies are produced by *exhalations* from the surface of the earth.

3. Some philosophers, dissatisfied with the methods which have now been mentioned, of accounting for the falling of stones from the heavens, have ascribed to them an origin still more extraordinary. They suppose them to be sent to us from the moon. By the aid of the telescope, luminous spots have been discovered on the moon, which, from their changeable appearance, are supposed to be volcanoes. If bodies can be projected from these, a certain distance towards us; they will never return, but will be drawn away by the superior attraction of the earth. There is a particular point, between us and the moon, in which, if a body were placed, the attraction of the earth and of the moon upon it would be equal. This point is calculated to be twenty-four thousand miles from the moon's center – about one tenth of her distance from the earth.

The velocity with which a body must be thrown from a lunar volcano, to reach this point of equal attraction, is about ninety miles in a minute – not more than one third of the velocity with which a meteor moves, when near the earth; and only three or four times as great as that with which a ball may be sent from the mouth of a cannon.

The atmosphere of the moon would probably oppose some resistance to the motion of a body passing through it; but far less than ours. It has so little extent and density, that its very existence has long been a subject of dispute among astronomers.

If the earth and the moon were at *rest*, and a body were sent directly from one to the other; it would strike it. But the moon has a revolution round the earth. Every body thrown from her surface, must partake of her motion in this orbit. The path described by a body projected from a lunar volcano, would not, therefore, be a *right line*, directed to the center of the earth; but a *curve*, which would be the result of a combination of the projectile force, the motion of the moon in her orbit, and the power of gravitation.\* The body, instead of striking the earth, would probably revolve around it. In some part of its revolution, it might fall within the *atmosphere*; and pieces detached from it, by violence, might be thrown to the ground.

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\*NOTE.....The editor of the late abridgement of the London Philosophical Transactions, (vol. vi. P. 108,) supposes, “that the apparent motion of the meteor, in a direction almost parallel to the horizon, may be owing to the motion of the earth, in its annual orbit: That, while the body is coming towards us, the earth *glides away*, and leaves it behind.” If this were the fact, the motion of meteors ought always to be in a direction contrary to that of the earth in its orbit; and therefore in the plane of the ecliptic. But they are observed to come from various points of the compass. That which exploded over Weston, moved in a direction almost *perpendicular* to the ecliptic. Besides, the motion of the earth in its orbit, is not in a line parallel to the horizon, except at noon and midnight. And indeed, it is not easy to see, how the apparent motion of a body projected from the moon, could be *in any way* affected by the annual revolution of the earth. For the moon has the *same* revolution. A body thrown from one to the other, partakes of the motion, which is common to them both. A ball fired from a ship under sail, at another ship, moving in the same direction, and with the same velocity, would not be prevented, by the motion of either vessels, from striking its object.

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This theory can perhaps claim one advantage over the others which have been mentioned, the merit of bare possibility. But its advocates appear not to have taken into consideration the size of the meteors, from which the falling stones proceed. They

attempt to give an account of those small pieces only, which are actually found on the ground. But these must be a very small portion indeed, of a body a mile or two in circumference. According to the observations of Dr. Herschell, the altitude of the mountains in the moon, does not generally exceed half a mile. These can be little larger than some of the meteors which appear in our atmosphere. Before we acquiesce in this theory then, we must be prepared to believe, not merely that the lunar volcanoes throw a few pieces of lava, as far as the earth; but, that they send us whole mountains.

Nor is this all. Among a number of bodies, thrown at random from the moon, it is not probable, that one in ten thousand would have precisely that direction, and that rate of motion, which would be requisite to cause it to pass through our atmosphere, without falling to the ground. Yet a meteor is seen, in some part of the world, almost every year. To account for this fact, by the theory in question, we must suppose, that thousands of bodies are annually thrown from the moon, each of which is several hundred feet in diameter. A pile of mountains as large as the Andes, would, at this rate, be very soon scattered.

4. There is one other hypothesis, which, though not entirely without difficulties, appears to be encumbered with fewer than any other, which has been offered to the public. Among the manuscripts of the Rev. Thomas Clap, formerly President of Yale College, was found a paper, containing "Conjectures on the nature and motion of Meteors." This was published, some years after his death. It is thought, that the theory of "Terrestrial Comets," which it proposes, may be so modified, as to suit the case of atmospheric stones.

The solar comets, it is well known, revolve round the sun, in very eccentric orbits. In one part of their revolution, they sometimes come so near as to almost strike his body. They then move off, far beyond the orbits of all the planets; and, in some instances, are gone hundreds of years, before they return. President Clap supposes, that the earth is furnished with its system of comets, as well as the sun -- that their size, and the period of their revolutions, are proportioned to the comparative smallness of the primary body, about which they revolve -- that, like the solar comet, they fly off, in very elliptical orbits; and, during the greatest part of their circuit, are too far distant to be visible -- that, in their approach to the earth, they fall within our atmosphere -- that, by the friction of the air, they are heated, and highly electrified -- that the electricity is discharged with a very violent report -- that they then move off in their orbits, and, by their great velocity, are soon carried out of our sight.

It does not appear, that the learned author of this theory was apprized of the fact, that substances frequently fall from these bodies to the ground. But the scheme requires very little alteration, to accommodate it to this circumstance. We have only to suppose, that, at the time of the explosion, pieces are broken off from the surface of the meteor; and that these fall to the earth, while the main body moves on in its orbit.

The hypothesis, if admitted, will account for most of the phenomena attending the fall of atmospheric stones. The *velocity* of the meteor corresponds with the motion of a terrestrial comet, passing through the atmosphere in an elliptical orbit. A body moving near the earth, with a velocity less than 300 miles in a minute, must fall to its surface by the power of gravitation. If it move in a direction parallel to the horizon, more than 430 miles in a minute, it will fly off in a curve of an hyperbola; and will never return, unless disturbed in its motion by some other body besides the earth. Within these two limits of

300 miles on one hand, and of 430 on the other, (some allowance being made for the resistance of the air, and the motion of the earth,) the body will revolve in an ellipsis, returning in regular periods. Now, the velocity of the meteors, which have been observed, has generally been estimated to be rather more than 300 miles in a minute. In some instances, it is perhaps too great, to suffer the body ever to return. But, in most cases, it is calculated to be such as would be necessary, in describing the lower part of an elliptical orbit.

The *direction* of the motion also, agrees with that of a revolving body; but not at all with that of a mass of matter, accumulated in the atmosphere, and falling, by its weight, to the earth. The *dimensions* of these meteors too, are such, as to indicate, that they move in orbits of their own; as they are manifestly too large to be formed in the air, by an accumulation of gases, or to be thrown from a volcano or the moon. They appear to have about the same proportion to their central body, the earth, as the little planets lately discovered between the orbits of Mars and Jupiter, have, to the sun, about which they revolve.

The theory last stated, 'though in the main adapted to the purposes for which it was proposed; yet, it must be acknowledged, is not entirely satisfactory, in the explanation of one or two particulars. It assigns a reason for the ignition and explosion of the meteor, which is not perhaps fully warranted by any observations and experiments hitherto made. The stones, when they fall to the ground, are found to be hot. The body of the meteor itself, has the appearance of fire. It is undoubtedly in a state of ignition, at least at the surface. Whence is this powerful heat derived? President Clap supposes it is produced by the friction of the air – that the body, moving with great rapidity through the atmosphere, is both heated and electrified – and that, when it is nearest the earth, the electricity is discharged, with an explosion, as much greater than thunder, as the meteor is farther distant, than the common region of the clouds. It is well known, that *hard* substances may be electrified, and even set on fire, by rubbing them together. But farther proof is wanted, to make it evident, that a body may be made red hot, by the mere friction of the air; especially of air, as greatly rarefied, as it must be, in that part of the atmosphere where the meteors move.\*

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\*NOTE.....Since the discovery of Mr. Davy, that the earths are metallic oxides; it has been suggested, that the bases of magnesia and silex, may originally exist in the meteor, in the state of *pure metal*; and that, when the body comes from some distant region of the heavens, into our atmosphere, a sudden and violent combustion is produced, by the very strong affinity of these substances to oxygen.

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There is another circumstance, which is left unexplained, by this theory. In a few instances, particularly that at Sienna, the falling of stones is said to have been accompanied, or preceded, by an apparent burning of the clouds. If this is anything more than an optical deception, it seems to indicate, a collection of combustible materials in the air. This appearance of fire in the heavens, has been too long before the falling of the stones, to be the *effect* of the passage of the meteor through the atmosphere.

With the exception of these two difficulties, neither of which ought perhaps to be considered as insuperable, the theory, which refers to the origin of the meteoric stones to terrestrial comets, appears to be embarrassed with fewer objections, than any of the

others which have now been mentioned. None of them, however, can claim to be considered as any thing *more* than theories. They are not yet supported by direct and positive proof. The subject is involved in too much obscurity, to admit of a complete elucidation at once. The enquire has commenced, with a number of suggestions, which *may* be true; but which must be left, to be confirmed or refuted, by subsequent observations. This is, not unfrequently, the course which scientific investigations must of necessity take. The first step towards an important discovery, is often an ingenious conjecture. This gives the lead to a train of inquiries, which finally succeed, in unfolding the true principles of the subject. It must be granted, that but little progress has, as yet, been made, in explaining the origin, nature, and use, of the bodies, from which the atmospheric stones proceed. But the facts that have been collected, have awakened curiosity. The approach of these meteors, will hereafter be noticed, with uncommon interest. Observations of their motion, will probably be made, with as much accuracy, as the opportunities furnished, by their sudden and unexpected appearance, will admit. But whether the mysteries of the subject will be unveiled, upon a farther investigation, time must determine.

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