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SOME THEORIES OF THE ORIGIN OF METEORITES.

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"And it came to pass as they (the Amorites) fled from before Israel and were in the going down to Beth-horon, that the Lord cast down great stones from heaven upon them unto Azekah and they died: they were more which died with hailstones than they whom the children of Israel slew with the sword."

These words from the 10th chapter of Joshua, 11th verse, are the earliest recorded account of a meteoric fall, or what could be taken for one, that I have been able to find. This event at the defeat of the Amorites by the children of Israel under the leadership of Joshua, took place, according to the received chronology, 1451 years before Christ.

Of the twenty-five whose fall has been recorded as occurring before the birth of Christ, that one has been mentioned by the highest authority which fell about the year 467 B. C. Pliny in the 2d book (58th ehapter) of his Natural History writes: "The Greeks boast that Anaxagoras a Clazomenian, in the second year of the 78th Olympaid, from his knowledge of what relates to the heavens, had predicted that at a certain time a stone would fall from the sun. And the thing accord-

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ingly happened in the day time in a part of Thrace at the River Ægos.* The stone is now (in the time of Pliny) to be seen a wagon load in size and of a burnt appearance. There was also a comet shining in the night at the time." Thus in a philosophizing way Pliny continues: "But to believe that this had been predicted would be to admit that the divining powers of Anaxagoras were still more wonderful, and that our knowledge of the nature of things, and indeed everything else, would be thrown into confusion were we to suppose either that the sun is itself composed of stone or that there was even a stone in it. Yet there can be no doubt that stones have frequently fallen from the atmosphere." And then after enumerating two or three falls within his knowledge he leaves us utterly in the dark touching his theory of the origin in space of these most remarkable visitors.

So then from very early times the occurrence of these falls has been noted. But as the external and internal characters of these stones thus scattered about on the earth were unknown until a very recent date, we have no definite data of the number of meteorites reaching the earth. It was only when one was seen to burst and scatter its fragments by a people with a written history that note of its arrival was made. Even now with much more of the earth's surface inhabited by historic and intelligent races, the sight of a meteorite is a very rare thing; and we can readily believe that centuries ago when one was seen to lodge upon the earth the event was heralded far and wide, and even was taken as a point of departure in the annals and the local traditions of the region.†

These balls of fire seen sweeping thro' the air, blazing and hissing along at lightning speed were believed to be messen-

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*Aristotle makes mention of this same fall.

†Instance the following to be found in the *Parian Chronicle:* "From the time when the stone fell at Ægospotamos (the fall just mentioned) and the poet Simonides, who died at the age of ninety, during the Archonship of Theagenides at Athens is 205 years."

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gers from heaven. Some god was offended with men or he had some heavenly service for men to perform; and so he made his presence felt or his mandate known in this impressive way.

Among the Greeks and neighboring nations it was the belief that Aerolites came from some point beyond the earth, as indicated by these words of Homer in his account of the siege of Troy:

> "So saying, Jupiter to Pallas gave
> The charge she wished already, she in haste
> Shot from the Olympian summits, like a star
> Sent by the crafty Saturn's son to warn
> The seamen or some mighty host in arms,—
> A radient meteor scattering sparks round.
> She came and lighted Pallas on the earth
> Amidst the armies. All who saw were seized
> With wonder,—Trojan Knights and well armed Greeks;
> And many a one addressed his comrade thus:
> 'Sure we shall have the wasting war again,
> And stubborn combat; or, it may be, Jove,
> The arbiter of wars among mankind,
> Decrees that the two nations dwell in peace.' "
>
> *Iliad IV, l. 75 et seq.*

Among the races of the north mythology shows that meteorites were greatly venerated. They were marks of remembrance from Thor, the god of thunder and lightning. Their flaming course thro' the sky and loud report heard at their arrival, were signs of their divine origin. Their excessive weight was an index of their author's might, for they were his tennis balls and only the smallest ones were sent down to a weakling race. This tradition, sprung up and to this day found in the folk-lore of Sweden, shows the deep rooted belief of the people that Thor was he who had sent these wonderful visitants to the earth*

*Symbolik d. Natur, p. 123.

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Continuing down we learn that in 1110 a fire ball fell into the lake Van. The greatest consternation seized the inhabitants,—they saw huge volumes of mud and watar rise into the air, long fissures appear extending over the ground and the waters of the lake turned into blood.*

Near Luzerne in Switzerland, in the fifteenth century, the fall of a meteoric stone was observed. The account relates phenomena similar to those seen in Armenia at the lake Van some three hundred years before. But the popular mind saw in it the egg of a dragon. Long and anxiously did the people wait for the period of incubation to expire and the young monster to rise from the earth. Many a house was set in order and many a preparation made for that day of destruction which, probably to the disappointment of many a wiseacre, never came.†

In all accounts of meteoric falls, at the present time accessible to us, except those of quite recent date and observed by intelligent men not steeped in superstition, the most absurd stories prevail. These representations pertain in the first place to the size of the masses, which have been described as varying from a wagon load (or adopting a modern standard of comparison, a prairie schooner) to a mustard seed. Usually they have been represented as like the moon, constantly increasing in size and striking with more and more force, the

*Taschenbuch der Mineralogie, 15 II. 614-15; became red.

†Two other instances might be mentioned: At Juvenas, in France, there occurred a fall of meteoric stones June 15, 1827. The inhabitants were so startled that they did not stir out to look over the ground until the 28th of the month.—[Amer. Jour. Sci. vol. 2 p. 175.

The following I translate: A rain of aerolites occurred near the end of November, 1833, at Kandahar, India. The stones were so large and fell so thickly that several roofs were pierced and others fell in ruins. A twelve year old child attempting to bring in a piece from the court, was struck dead by another falling. The fall was succeeded by a fog so thick that the sun was three days in penetrating it.—[Neues Jahrbuch fur Mineralogie, 1837, page 126.

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imagination of the beholder as they neared the earth, until an explosion would shatter not only the meteor but all regard for truth and veracity in the expectant people. A diameter of one or two miles was considered not at all improbable—that was only an ordinary affair—for a large one. Statements of the rate of flight, too, varied. Estimates here being as wild as in estimates in size, loudness of the report made when the ball exploded, and the other attendant phenomena.

Then as to the height at which they have been seen. In the statements of those seen before tne eighteenth century the height was scarcely ever less than fifty miles. As we come forward one hundred years the average has been reduced to less than twenty miles. During the last twenty-five years but few masses have been seen higher than five miles.*

These exaggerated guesses concerning the size, rate of flight, and height at which meteorites have been seen, have been owing no doubt to ignorance on the part of observers of somc simple physical laws, and the deep seated superstition which associated horrors of any possible kind as sequences of these super-terrestial omens, accompanied as they were with trains of light, loud sounds, the raining of solid matter upon the earth and sulphurous odors.

And the scientific observations of the day tended to confirm unscientific sight and hearing and smell. For instance: the Hanoverian astronomer, Schrœter, in 1796, announced that as he was gazing into his telescope he saw a point of light flash across the field of view, not less than 1000 miles high. Ben-

*At Braunau, Bohemia, an ærolite fell July 14, 1847, which was seen to burst in the air. The two main pieces were found, one of which buried itself three feet in the earth, and the other entered a house, crashing through thatch, rafters and ceiling. The distance apart of these pieces together with the angle of direction observed in the course of the latter through the woodwork of the house, gave about 29,000 feet as the altitude at which the body must have burst.—[Neues Jahrbuch, 1847, p. 853.

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zenberg of Hamburg, who saw the same point of light, estimated its height at 700 miles. Without throwing the least doubt over the accuracy and trustworthiness of these astronomers, I will merely add that almost unhesitatingly the consequent of the syllogism was added and meteorites immediately went up to an inconsiderate height.

The long passage, too, made by some meteorites then observed, tended to strengthen the popular idea, exaggerated as it was. A ball of fire first seen in Dalmatia, on the 3d of March, 1676, passed diagonally across the Adriatic sea, over Italy, and was last seen passing away to the west towards Corsica. Another on August 18, 1785, was first seen flying over Scotland; consecutive observations traced it over England, France, Italy and away out of sight to the southeast.

Then it is not so very strange that these curious and mysterious falls of stone and iron-masses from heaven, should have exerted such a powerful influence over the beliefs of mankind,—even to the extent of entering into the religions of many peoples. That such is the case we can refer to several strongly corroborating passages. The verse from Joshua already read, shows what could have been understood by many af the Jews: the stone Hajar el Aswad, so sacred to the Mohammedans that it forms an object of adoration by the pilgrims to the Kaaba at Mecca, is doubtless one of these meteoric bodies: the passage in Acts 19:35 is interpreted by some holding the Christian faith to refer to a mass of peculiar shape which once fell from heaven.

But gradually, as more falls were noticed, people naturally accumulated particulars and compared phenomena. A more careful study of these objects may be seen to have begun with the fall at Ensisheim in upper Alsace, on the 7th of November, 1492, when a stone weighing 270 pounds struck the earth. This mass was broken up and widely distributed for specimen pieces; but at last the 70 pounds remaining was

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given to the village church at Ensisheim, where I believe it still remains.

This meteorite, however, was not examined chemically and mineralogically until years afterward.

So one mass after another was seen to fall or was found lying upon the earth, with no means offered of getting further data until 1776, when John Simon Pallas brought home from Siberia the celebrated mass of Pallas iron.

Pallas, who was a German by birth, was called to Russia in 1768 by the Empress Catherine II. as professor of natural science in the academy of St. Petersburg. A large part of the Russian Empire at that time was an unexplored region and one of the objects of the government in inviting foreign scholars into the country was to develop geographical and scientific knowledge. For some years Pallas traveled, passing through Siberia and even to the frontier of China. He collected with a wonderful zeal from every field of natural history, and brought back to St. Petersburg a huge collection of material of every description. Many of these specimens are to this day said to be amongst the most conspicuous attractions in the Academy's collections. One of the things he brought back was a piece of native iron weighing forty-two pounds, which he gathered in Siberia from a mass of 1600 pounds weight. This remarkable objcct, discovered it is claimed in 1776, has been one of profound interest to science; accordingly the scientific world, in acknowledgement of this interest and of the service of its collector, has with one accord united in giving it the name of *Pallas Iron*.

This was not the first meteoric iron known; two masses (16 and 17 pounds respectively) fell at Agram in Croatia, May 26, 1751, and this Croatian fall is the only one *of iron* which, until 1819, had ever been seen.

The Pallas Iron had a mixture of non-metallic mineral; so standing in mineral composition between a meteoric stone and

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a true meteoric iron, it was indeed a puzzle to the wisest heads of that day.

It was described physically by a Frenchman named Boumon, and a chemical analysis was made by an Englishman named Howard.

This Pallas Iron aroused universal interest and many were the theories of its origin suggested by different minds. One man, Erust Florens Friedrich Chladni, whose name is familiar to those who have studied acoustics, by its connection with certain vibratory plates on which, with a schoolboy, a fiddle-bow and a little fine dust, an infinite variation of sounds and figures can be produced, had given up his practice as a lawyer that he might pursue more uninterruptedly his investigations in natural and physical science. When the report of this wonderful piece of native iron and olivine reached him and its physical and chemical characters were made known, Chladni, as well as others, began to wonder whence this mysterious visitor came *if* it came from beyond the bounds of this world. So he collected all the data possible, not only concerning this Pallas Iron, but also concerning all others of which he could hear or collect specimens. And he wrote a memoir which was published in Riga in 1794, "On the Origin of the Mass of Native Iron found by Pallas, &c."

In this memoir Chladni declared it as his opinion that falling stars, fireballs, meteorites, meteoric iron, meteoric dust, etc., were one and all of cosmical origin, i. e., that they were bodies which, so far as they reach our earth, come to us from the common space occupied by the universe. This assertion was at first universally derided, but it has now become the only tenable theory of their orgin held by scientific men, though the particular part of that space from which they spring is still a matter not unanimously decided upon.

Chladni at first dared to affirm no more; but he continued his observations, collecting statistics of every fall where it was

possible to obtain any data whatever, making note of every new chemical ingredient discovered, studying all their physical characters, as specific gravity, hardness, adhesion, etc., until 1819, when he published in Vienna a very exhaustive memoir, which has been ranked as one of the few classics this subject has thus far called forth. It was entitled: "Ueber die Feuer-Meteore und die mit Denselben Herabgefallenen Massen" (On fire meteors and the masses which have fallen to the earth with them). In this Vienna memoir Chladni stated many of the phenomena attending the falls of meteorites which I have already mentioned, and many more that it would appear like detail to repeat. He further classified these masses into 1, METEORIC IRON; 2, METORIC STONES; and 3, METEORIC DUST.

The meteoric iron could be mixed with earthy or mineral constituents:

The meteoric stones—called properly *meteorolites*, because this term very exactly defines these masses as bearing every characteristic of rock in their physical and chemical natures—the meteorolites Chladni saw from his collections could by their material unerringly be distinguished from any terrestial rocks, both in the chemical and in the physical characters of the constituent minerals.

He observed that many meteorolites crumble easily, even between the thumb and finger, yet the finer grains are so hard as to offer a powerful resistance to being crushed; again, the mass is very hard and firm throughout, and offers as much resistance as the ordinary metamorphic rocks or basalts.

Others still are porous, and will allow air to be blown through them, and will absorb water with avidity; yet never, so far as he could observe with the material at his hand, were there cavities in these bodies with the single exception of the one which fell at Chantonay in 1812. The specific gravity in most specimens stood between 3.36 and 3.7—just about the

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same as that of certain very impure iron ores, and considerably above that of granite or basalt. In the meteoric irons the specific gravity varies between 6.5—8. The form of meteorites also attracted Chladin's attention. He admitted that at first they appeared to have no regularity of outline whatever, yet persistent study disclosed to him the fact that there was a striking similarity in their total form. I quote: "A certain ground-form, which, according to all appearances, restricts itself to an unequal-sided triangle or rectangular prism and to a more or less complete pyramid, seems to be the foundation: hence in the most irregular masses this regularity of form can to some degree be traced."*

The form of meteorites as given in the oldest chronicle extant is in general that of a somewhat irregular three- or four-sided pyramid. The pyramid is the form seen on all ancient Grecian coins, where a meteorite placed upon a pedestal and surmounted by a blazing star was a symbol used to represent the present and to point to the glorious origin of the state.

The peculiar incrustation seen covering all meteorites both iron and stone attracted attention. After describing quite minutely the appearance and, so far as he was able at that day to do, the structure of that part, Chladni concluded that it was nothing at all similar to the material thrown out of our modern volcanoes nor resembling in the remotest degree any thing found coming from the volcanoes of long ago, nor did it resemble the artificial products of smelting furnaces.

As chemical constituents of meteorites there had been determined at that time (1819) these elements as probably native: iron, nickel, chromium, sulphur, manganese and Carbon—and the following compounds: Ferric oxide, Ferric sulphide, silica, magnesia, lime, alumina, soda, potash, hydrochloric acid and water.

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*Taschenbuch, Vol. 15, II, p. 603.

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meteorites come. A limited supply of oxygen as a gas would explain the presence of certain silicates, because some substances have a greater affinity for oxygen than others.

And thus proceeding, in a clear and concise argument, Dr. Smith reaches the theory of the lunar origin of meteorites. We cannot follow it; time permits referring to this point only: Many astronomers concur in the opinion that a velocity of about 8,000 feet per second would project a body beyond the point of equal attraction between the earth and moon and cause the same to become a satellite of the earth. But Dr. Peters noted that stones from Ætna have attained a velocity of 1,250 feet per second, and observations on Teneriffe have given 3,000 feet per second as the rate of projection. Even this, it will be seen, is considerably slower than that necessary in the moon to produce the required velocity for making a satellite of the earth. "To sum up the theory of the lunar origin of meteorites, it may be stated that the moon is the only large body in space of which we have any knowledge possessing the requisite conditions demanded by the physical and chemical properties of meteorites; and that they have been thrown off from that body by volcanic action (doubtless long since extinct), and, encountering no gaseous medium of resistance, reached such a distance as that the moon exercised no longer a preponderating attraction. The detached fragment, possessing an orbital motion and an orbital velocity, which it had in common with all parts of the moon, but now more or less modified by the projectile force and new condition of attraction in which it was placed with reference to the earth, acquired an independent orbit more or less elliptical. This orbit, necessarily subject to great disturbing influences, may, sooner or later, cross our atmosphere and be intercepted by the body of the globe."*

*Scientific Researches, p. 310.

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Mr. Sorby* in examining thin sections of many different materials under the microscope sees proof that the usually black, varnish-like crust, so thin and brittle, which always covers meteors, was formed by fusion of the outer layer, under conditions not affecting the interior part. This crust is a true glass filled with bubbles formed by some agency not acting to a greater depth than 1-100 of an inch. The chemical composition of this crust shows that an oxidation took place at the time of melting. In the interior the grains and larger crystals are much broken and shattered. In the latter this brings out tho cleavage planes sharp and clear. These particles frequently contain a great many so-called glass cavities, but no fluid cavities. Glass cavities are formed by the sudden cooling of a molten mass containing gas bubbles, and are frequently found in igneons rocks; while fluid cavities are found in sedimentary and metamorphic rocks, when in the slow solidification a liquid or a liquefiable gas was present and became permanently imprisoned.

These crystals in meteorites are occasionally very large. The Estherville meteorite contains crystals of olivine between one and two inches across, but usually they are small with rounded angles and edges, probably the result of heat subsequent to their formation.

Meteorites also show fissures and veins. The former, no doubt, in their minute ramifications are the cause of the brecciated appearance seen in some falls; the faulting and healing and unequal consolidation occasionally met with, can be referred here. The veins are filled with some different material from that constituting the mass; plainly a case of the injection rather than the infiltration mode of filling veins.

Mr. Sorby's experiments with chilled iron, malleable bar iron, cast steel, Bessemer metal, &c., show that those inter-

*Abstract of lecture on Structure and Origin of Meteorites. *Nature* April 5, 1877.

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esting lines called the Widmanstattian Figures, from the man Widmanstatt, who first observed them, which can be brought out by wetting a polished surface of meteoric metal with nitric acid, are conspicuous and finely detailed only when separation and crystallization of the different metals has taken place under a slow and gradual cooling. These peculiar Widmanstattian figures are by no means confined to meteoric irons.

In conclusion, I will quote the following from the interesting paper last referred to: "Taking, then, the above facts into consideration, it appears to me that the conditions under which meteorites were formed must have been such that the temperature was high enough to fuse stony masses into glass; the particles could exist independently one of the other in an incandescent atmosphere, subject to violent mechanical disturbances; that the force of gravitation was great enough to collect these fine particles together in solid masses, and that these were in such a situation that they could be metamorphosed, further broken up into fragments and again collected together. All these facts agree so admirably with what we know must now be taking place near the surface of the sun that I cannot but think that, if we could only obtain specimens of the sun, we should find that their structure agreed very closely with that of meteorites. Considering also that the velocity with which the red flames have been seen to be thrown out from the sun is almost as great as that necessary to carry a solid body far out into planetary space, we cannot help wondering whether, after all, meteorites may not be portions of the sun recently detached from it by the violent disturbances which do most certainly now occur, or were carried off from it at some earlier period, when these disturbances were more intense. At the same time * * some of the facts * * may indicate that meteorites are the residual cosmical matter not collected into planets, formed when the

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conditions now met with only near the surface of the sun extendend much further out from the center of the solar system. The chief objection to any great extension of this hypothesis is that we may doubt whether the force of gravitation would be sufficient to explain some of the facts. In any case, I think that one or the other of these solar theories, which, to some extent, agree with the speculations of the late Mr. Brailey, would explain the remarkable and very special microscopial structure ot meteorites far better than that which refers them to portions of a volcanic planet, subsequently broken up, as advocated by Mennier, unless, indeed, we may venture to conclude that the material might still retain its original structure, due to very different conditions, previous to its becoming part of a planet. At the same time so little is postively known respecting the original constitution of the solar system, that all these conclusions must to some extent be looked upon as only provisional."