SKETCHES IN THE HISTORY OF METEORITICS 1: THE BIRTH OF THE SCIENCE

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The change of opinion concerning the stories of stones falling from the sky that took place around 1800 is examined. The meteorite literature during and after 1803 shows that a decisive role was played by the chemists Howard, Vauquelin, Fourcroy, and Klaproth, the importance of which exceeded that of J.B. Biot's report on the fall of L'Aigle. Biot's report underlined the change of opinion brought about by the chemical work. The importance of chemistry at this stage probably had a considerable influence on the history and possibly even the present nature of meteoritics.

INTRODUCTION

It is often stated that the science of meteoritics was initiated by E.F.F. Chladni in 1794, when he ascribed an extraterrestrial origin to the falling stones and several large masses of native iron then known, and that it became generally accepted as a consequence of Biot's report on the fall of the meteorite at L'Aigle. No doubt this is a gross oversimplification. It is, however, true that reports of stones falling from the clouds were very largely scorned in the 1780s but had found a respectable place in the mineralogical and astronomical textbooks by 1810. The state of opinion before, and to some extent during, the transition period is amply illustrated by Table 1, taken from Izarn's "Lithologie Atmospherique," published in 1803. Supporters of eminence existed for all the ideas that had been proposed, which is perhaps indicative of the lack of firm evidence for any particular theory. The presence of Poisson's and Biot's names alongside Chladni's as favouring an extraterrestrial origin is highly significant and a point to which we will return later. But a year or two before this table was drawn up, the most generally expressed view was that of the scorn shown by the often quoted Berthollet (see Krinov, 1960, page 9) and even as late as 1801 we find the same attitude presented as the accepted one (Anonymous, 1802):

> The rarity of these phenomena, however, which has not allowed of their being seen at a short distance by observers possessed of intelligence, and at the same time worthy of credit, and which seems hitherto to have reserved them for the eyes of the vulgar, so much inclined to exaggeration, has prevented the learned from believing in the existence of these stones.

Table 1
Principle opinions concerning the origin of stones falling from the sky from *Lithologie Atmospherique* (Izarn, 1803)

Volcanoes or hurricanes		Concretions in the atmosphere	
Freret	Barthold	Descartes	Sir William Hamilton
Gassendi	Deluc	Lener	Edward King
Muschenbroek	Delalande	Goyous-d'arzas	Salverte
Lightning fusing terrestrial rock		**Masses foreign to our planet**	
Lemury	Stahl	Chladni	Poisson
Academicians	Gronberg	Biot	Bibliotheque Britanique
Agricola	Patin		

It was only after the widespread acceptance by the scientific community that stones actually fell from the sky, from what was probably a common origin, that a study of them began in earnest. It is with this change in opinion that we are concerned with here. An examination of the literature of the time shows that a crucial role was played by the chemists Howard, Vauquelin, Fourcroy and Klaproth.

CHLADNI

Chladni's reasons for believing in an association between the "native irons" and reports of falling stones were the signs of intense heating which the irons had obviously suffered, their dissimilarity with local country rocks and the implausibility of any other explanation (Chladni, 1794). The Pallas iron, Fig. 1, does not play as important a part in his book as it does in the title, being just one of five such masses found in various parts of the world, and although he visited St. Petersburg in 1794 it is doubtful he ever saw the mass (Paneth, 1958). What Chladni lacked was a definite link between these large masses and the stones that were actually seen to fall. In the light of current knowledge the iron masses in no way resembled terrestrial rocks but the stones did, and these could readily be explained as terrestrial rocks struck by lightning, Table 1. However the stories of masses falling from the sky nearly always concerned stones. This must have been a major difficulty for the general acceptance of Chladni's hypothesis. The dissimilarity between the native irons and terrestrial rocks was emphasized by the discovery of the French chemist Proust that one of the irons to which Chladni referred, that found by Rubin de Celis in Argentina, contained nickel (Celis, 1788; Proust, 1800). Proust, however, was more concerned with the commercial implications since the iron's nickel content appeared to make it rust less easily. This was pursued later by, among others, Michael Faraday.

Fig. 1 **The Pallas Iron from Vol. III of P.S. Pallas' "Reisen durch verschiedene Provinzes des Russischen" (St. Petersburg, 1776).**

In 1795 a fall occurred at Wold Cottage, a village in Yorkshire, England. The 56-pound stone and affidavits testifying to its fall were put on display in a London coffee house and soon came to the attention of Sir Joseph Banks. As president of the Royal Society and a well known collector, he often received mineralogical and botanical specimens. In this way he had previously been sent meteorites from Siena (Italy) and Benares (India) and was impressed by the similarity of the three stones. To see if this similarity was more than superficial he asked the Honourable Edward Charles Howard (Sears, 1975), a young and respected chemist to whom he had recently awarded the Copley Medal of the Royal Society, to undertake chemical analyses.

EDWARD CHARLES HOWARD AND THE CHEMICAL WORK

Unlike the other participants of this story, little is known about Edward Charles Howard, Fig. 2. He was born in Sheffield in 1774 to Henry Howard, an aristocrat and a distant relative of the ninth Duke of Norfolk. The family were staunch Roman Catholics so that, like his two elder brothers, he was educated privately and in France at the English College at Douai. By the time he was 25 and living in London he was elected a Fellow of the Royal Society. As with many contemporaries this was probably as a consequence of his aristocratic background but he soon made respectable contributions to chemistry. In 1800 Howard discovered mercury fulminate and later fulminating silver. It was for this that the Royal Society presented Howard with the Copley Medal, its highest scientific award. At the presentation in December, 1800, Banks first mentioned meteorites in Howard's connection and also revealed his own feelings about them (Banks, 1800):

> Mr. Howard has not stopped here. He has announced to us the discovery of his fulminating silver, analogous in some degree to his fulminating mercury, and he is now employed in the analysis of certain stones, generations in the air by fiery meteors, the

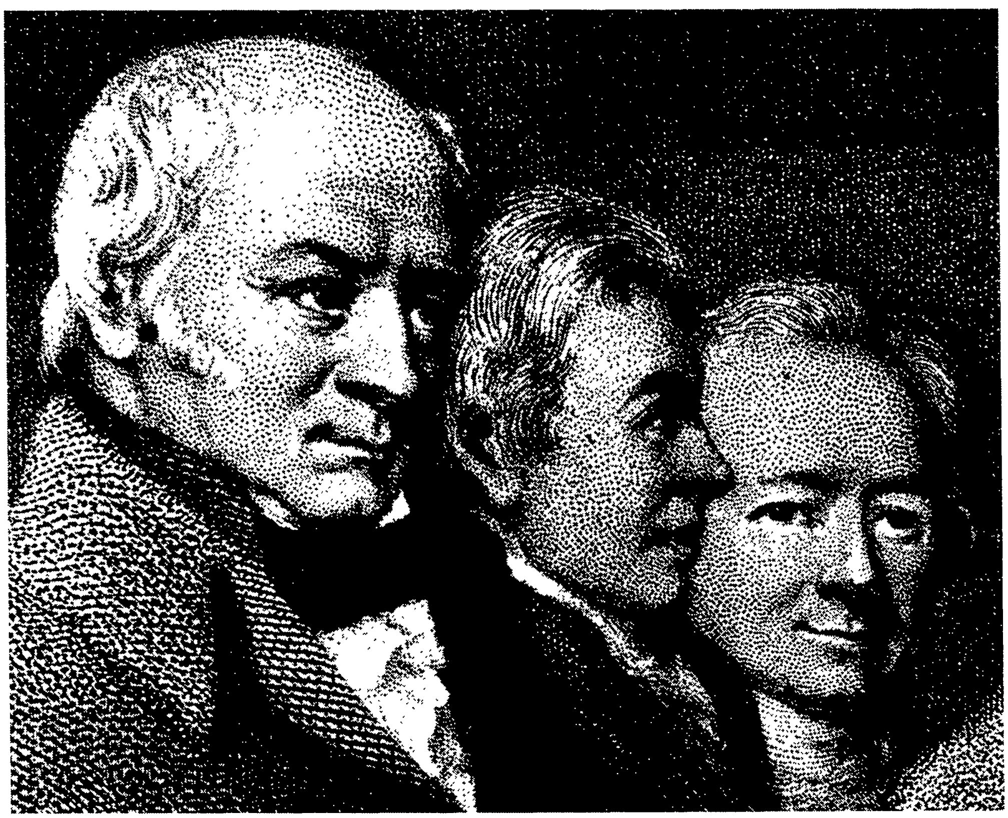

Fig. 2 Edward Charles Howard from an 1863 engraving by W. Walker. In front of Howard is William Smith (geologist) and behind William Allen (chemist).

> component parts of which will probably open a new field of speculation and discussion to mineralogists as well as to meteorologists.

Howard enlisted the help of Jacques-Louis Compte de Bournon (1751-1825). Bournon was a French mineralogist who was in England at that time to escape the turbulence of the French revolution (Gillespie, 1970). Together they examined Benares, Wold Cottage, Siena and Tabor and the native irons Senegal (Siratik), the Otumpa iron (Campo del Cielo), Bohemia and the Pallas iron (Krasnojarsk). The chemistry revealed a remarkable similarity between the stones and, even more remarkable, that the metal grains in them, like the native irons, contained nickel. Here was the link that Chladni lacked. To Howard the consequences of these findings were obvious, but he stated them with great care and deliberation, with due regard to the current climate of opinion (Howard, 1802, page 212):

> From these facts, I shall draw no conclusions, but submit the following enquiries.
>
> 1st. Have not all fallen stones, and what are called native irons, the same origin?
>
> 2ndly. Are all, or any, the produce or the bodies of meteors?

A number of additional findings of considerable interest but of less significance at the time were made by Howard and Bournon. Howard was the first to observe the uniqueness of meteoritic iron sulphide, the ability of the stones to luminesce when suitably stimulated and the chloride droplets on the irons produced by lawrencite decomposition, which he did not publish as he thought it was an artifact. Bournon's findings were no less original. He was the first to observe chondrules, the significance of which was to be appreciated only with the introduction of thin sections in the 1850s, and identified the "glass" of Krasnojarsk as olivine. All the features, unique to the stones and irons, were common to them all regardless of their country of origin and this was the most important point to emerge from Howard's work.

Howard's results appeared in the Philosophical Transactions for 1802. Immediately afterwards he visited the French chemist Vauquelin in Paris where he learned that although the same work had been performed it was unpublished. Howard persuaded Vauquelin to publish since it confirmed his results, Table 2. Similar agreement was also about to come from Klaproth (1803) in Berlin. The continent's two most respected chemical analysts were therefore in agreement with Howard. At this point, however, he drops out of the story. Howard's inclinations were becoming more those of the inventor and as such he made his fortune in the sugar industry. However his work was to dominate thinking about "meteor-stones" for many years.

In the autumn of 1802 Professor Pictet, a member of the French Academy who was particularly interested in meteorites at this time, presented

Table 2
Chemical analyses mentioned in the text (percentages)

		Silex (SiO_2)	Magnesia	Iron Oxide	Nickel	Sulphur	Lime
Academicians[1]	Lucé	55.5		36	–	8.5	–
Barthold	Ensisheim[2]	42	14	20	–	2	2
Howard	Wold Cottage	50	24	32	1.3	–	–
	Benares	47	23	35	2	–	–
	Siena	46	22	34	2	–	–
	Tabor	45	17	42	2.7	–	–
Vauquelin[3]	Benares	48	13	38	3	–	–
Fourcroy	L'Aigle	54	9	36	3	2	1
	Ensisheim	56	12	30	2.4	3.5	1.4
Klaproth	Siena[4]	44	22	27	0.6	4	–

[1]Did not distinguish between silex and magnesia, referring simply to "vitrifiable matter."
[2]The analysis also included 17% alumina.
[3]Also analyzed Creon and Barbotan, which were similar, but did not publish results.
[4]The analysis also included 2% manganese.

Howard's results to the Academy and a few months later Vauquelin confirmed them. According to Salverte (1803) and Lacroix (1803) a discussion followed the presentation of Vauquelin's paper of February 10, 1803. In Salverte's words Biot and Laplace put forward the "very bold opinion, rendered probable by the celebrity and character of its authors" that the stones could have had a lunar origin. Laplace and Biot, and also Poisson (1803) who at this time also came out in favour of a lunar origin, were clearly convinced of the authenticity of meteorite falls by the chemical arguments. Their suggestion was made in an attempt to rationalize and therefore make the phenomenon seem more acceptable, and it was supported by simple calculations. Herschel's observations of active lunar volcanoes no doubt helped the idea (Herschel, 1787). Laplace had previously discussed the possibility of the stones having a lunar origin after the much publicized fall of stones at Siena, Italy, in 1794, but at that time favoured a terrestrial volcanic origin. This was a natural conclusion because the fall occurred after an eruption of Vesuvius (Hamilton, 1795).

Vauquelin's paper confirming Howard's results was presented more than two months before the fall of the L'Aigle meteorite. This fall was first mentioned in the French Academy on June 19, 1803, by Fourcroy. Fourcroy was a chemist of almost equal stature to Vauquelin and the two often worked together (Gillespie, 1970). After presenting various letters they had received describing the fall, he announced analyses which were very similar to those already published (Fourcroy, 1803). He also displayed specimens of the Salles (1798) meteorite, which bore a close resemblance to the L'Aigle stones (Drée, 1803).

This, then, was the situation before Biot was sent by Chaptal, the Minister of the Interior, to investigate the L'Aigle fall. In England the president of the Royal Society and Howard accepted that meteors, the stones, and the native irons were of common origin; in France, Vauquelin and Fourcroy had confirmed Howard's analyses and were therefore of the same opinion and Laplace, Biot and Poisson had proposed a lunar origin. In Germany, Klaproth had come to the same conclusions. Biot left Paris for L'Aigle on June 26, 1803, and presented his report to the Institute on July 19.

THE CHANGE OF OPINION

Biot's report (Biot, 1803) was well argued and contained many testimonials by irrefutable witnesses, probably the most influential being Leblond since he was a member of the Academy (Biot, 1803, page 18). However it would not have been complete without the chemical arguments. The report started (page 6) with a review of the findings of Howard and the other chemists, and ended (page 46) with an analysis of the L'Aigle meteorite which he observed closely resembled the others. The importance of the chemical work was clearly appreciated by him. In contrast to the papers of Howard, Vauquelin, Fourcroy and Klaproth, which are full of dry details of analytical techniques and tables of figures, the report is dramatic and exciting. It is therefore not surprising that it is usually cited as the reason for the general acceptance of the idea that stones were falling from the sky. Clearly, however, several were already convinced by the analyses and Biot's report may have played only a minor role. We can perhaps best understand what happened by asking why the change occurred at this time.

The time of the change of opinion coincides very closely with that of the fall of L'Aigle. But this cannot be cited as the cause because many falls, for example Siena (1794) and Salles (1798), received as much attention. Secondly, as we have seen, a number of people already had been convinced. Neither can Chladni's book alone have prompted the change of opinion because several other authors, some highly respected, had made similar suggestions many years previously, for example, Halley, Maskelyne and Troili. Chladni was a well established physicist, more so than Biot who was at that time still unaccomplished. But unlike the other, earlier, proponents of an extraterrestrial origin, Chladni's suggestion was followed rapidly by the analyses of Howard, Vauquelin, Fourcroy and Klaproth. Analyses had been made before. Barthold (1800) had analyzed Ensisheim and the Academicians (Fougeroux *et al.*, 1772) had analyzed Lucé, Table 2. There were, however, two major differences between these analyses and those made subsequently. Firstly, the more recent chemists knew about the existence and chemistry of nickel. Although Barthold must have known of this, he had not realized the need to separate the phases and the presence of nickel was not so easy to detect. To Howard, working closely with a mineralogist, the need to separate the phases was obvious and the discovery of nickel certain. Secondly, and more important, Howard, Vauquelin, Fourcroy and Klaproth had several meteorites to analyze and it was the similarity of meteorites that had fallen widely apart that was significant. The availability of specimens is attributable to the great vogue for collecting, which reached its peak in the late eighteenth century, and the large number of falls at that time. Another important factor must have been the native irons. Several were known by 1800 and, because of the large number of private collections, specimens were wide-spread. General interest in them probably prompted Chladni to specifically mention one of them in the title of his book when in fact it plays only a minor role (Wasson, 1974). The discovery of nickel in them and in the metal of the stones was soon realized to be the highly significant link needed in Chladni's argument. It was Chladni's book, followed by the chemical work made possible by the availability of specimens, that caused the change in opinion to occur at this time and not the fall of L'Aigle and Biot's report.

A survey of the meteorite literature in the decade or so after 1803 shows that this was the case and one may quote innumerable examples. For example, Olbers, who discovered the second asteroid Pallas in 1802 (and later the asteroid Vesta), was persuaded by Howard's results to give up his view that meteorites were volcanic in favour of a lunar origin (Olbers, 1803):

> It has been lately shown by the mineralogical description of Count de Bournon, and the chemical analysis of Mr. Howard, that the stones found at Siena have a perfect resemblance to all the other stones which have been seen to fall from the heavens, and which certainly cannot be productions of our earth. My former explanations and conjectures fall therefore to the ground, and we must class the stones of Siena among those which are formed by nature in some mode with which we are unacquainted, and which bursting always with the appearance of light fall down to the earth.

After calculating that lunar, but not terrestrial, volcanoes could readily throw large rocks considerable distances he continues:

> It appears then, that it is not altogether impossible that the stones or masses which have been seen to fall from the heavens, and which, though entirely different from all the mineral bodies of our earth, have a great resemblance to each other, may have fallen from the moon. It is in their great similarity and correspondence that the grounds of this opinion are to be found, for the similarity of external appearance, and of their component parts, evidently show that they have all had the same origin.

It is evident from Lacroix's report of Vauquelin's presentation of his work to the Academy of Sciences that he too was inclined to believe in an extraterrestrial origin because of the chemical work (Lacroix, 1803):

> These (Vauquelin's) results, analogous to those obtained by Mr. Howard, and the work in which Dr. Chladni, known by his ingenious experiments on vibrating surfaces, had collected all the accounts published respecting the fall of these stones, concur to render that their origin is foreign to our globe; for hitherto none of a similar kind have been found in the interior parts of it.

Proust (1805) in his description of the fall of Sena; Hutton, Shaw and Pearson in their footnote to Halley's article on meteors in the Philosophical Transactions Abridgements (Hutton *et al.*, 1809); William Higgins (1819) in his article on the Limerick meteorite; Bakewell (1819) in his "Introduction to Mineralogy"; and Berzelius (1834) in his important paper "On Meteoric Stones": all give the chemical work as the reason for the general acceptance by the scientific community of the fall and extraterrestrial nature of meteorites. As early as 1806 James Sowerby, in his classic work on British mineralogy, found it more necessary to explain why he included the stones in a textbook on mineralogy than to explain why he believed them to have fallen "like a meteor from the skies." But while he repeatedly referred to Howard's work, to the extent of eventually reproducing some of his analyses in total, he did not mention Biot's report on L'Aigle. It seems that only in comparatively recent times has Biot's report found the eminence ascribed to it by modern textbooks.

CONCLUSIONS

The analyses by Howard, so rapidly and accurately confirmed by Vauquelin, Fourcroy and Klaproth, were responsible for changing the opinion of the scientific world concerning the authenticity of meteorite falls and their extraterrestrial origin. In doing so they laid the basis for research for the first few years of the life of meteoritics. For throughout its first few decades the reins of the young science were firmly in the hands of the chemists, and the extent to which this determined its history and present nature is a topic for considerable further study.

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