KRINOV, E.L. 1955. *Principles of Meteoritics*. Fesenkov, V.G. (ed.). State Publishers of Technical/Theoretical Literature, Moscow (in Russian).

KRINOV, E.L. 1981. *Iron Rain*. Moscow. Nauka, Moscow, 192 (in Russian).

MASSALSKAYA, K.P. 1954. E. F. Chladny – a founder of scientific meteoritics. *Meteoritika*, **11**, 33–46 (in Russian).

MUKHIN, I.M. 1819. *On Miraculous Showers of Stones Falling From the Air (Aerolithes)*. Imperial Foundling-Hospital Publisher, St Petersburg, 207 (in Russian).

NAZAROV, M.A. 2000. The meteorite collection of the Russian Academy of Sciences. *In*: ALEKSEEVA, T.I. (ed.) *Museums of the Russian Academy of Sciences*. Scientific World, Moscow, 47–62.

PALLAS, P.S. 1786. *Travels in Various Provinces of the Russian State*, Volume 2, 2, 385–482. Imperial Academy of Sciences Press (in Russian, the book was also published in German and French).

PANETH, F.A. 1940. *The Origin of Meteorites. Halley Lecture*. The Clarendon Press, Oxford, 26.

SEARS, D.W. 1975 Sketches in the history of meteoritics 1: the birth of the science. *Meteoritics*, **10**, 215–226.

SEVERGIN, V.M. 1811. A report on air stones or airolithes preserved in the Museum of the Imperial Academy of Sciences. *Technological journal*, **VIII**, 129–132 (in Russian).

STEHLIN, JA. 1809. On a New Map of the Northern Archipelago, and specimen of native iron. *Philosophical Transactions of the Royal Society of London*, **LXIY**, 1774, 461.

STOIKOVICH, A. 1807. *On Aerial Stones and Their Origin*. University of Kharkov, Kharkov, 271 (in Russian).

SVIATSKY, D.O. 1915. *Astronomic Phenomena in Russian Historical Chronicles Considered from a Scientific Point of View*. Bulletin of the Department of Russian Language and Linguistics of the Imperial Academy of Sciences 20, book 1 and 2. Petrograd, 214 (in Russian).

SVIATSKY, D.O. 1928. Similar features of meteorite phenomena at Tunguska in 1908 and Great Ustyug in XIII century. *Mirovedenie*, **17**, 117–119 (in Russian).

VERNADSKY, V.I. 1941. Some thoughts on problems of meteoritics. *Meteoritika*, **1**, 3–22 (in Russian).

Meteorites and the Smithsonian Institution

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Abstract: Meteoritics at the Smithsonian Institution is intimately linked to the broader growth of the science, and traces its roots through influential individuals and meteorites from the late 18th century to the dawn of the 21st century. The Institution was founded with an endowment from English mineralogist James Smithson, who collected meteorites. Early work included study of Smithson's meteorites by American mineralogist J. Lawrence Smith and acquisition of the iconic Tucson Ring meteorite. The collection was shaped by geochemist F.W. Clarke and G.P. Merrill, its first meteorite curator, who figured in debate over Meteor Crater and was a US pioneer in meteorite petrology. Upon Merrill's death in 1929, E.P. Henderson would lead the Smithsonian's efforts in meteoritics through a tumultuous period of more than 30 years. Collections growth was spurred by scientific collaborations with S.H. Perry and the Smithsonian Astrophysical Observatory, and a sometimes contentious relationship with H.H. Nininger. Henderson played a key role in increasing meteorite research capabilities after the Second World War, placing the Smithsonian at the forefront of meteoritics. After 1969 involvement in the fall of the Allende and Murchison meteorites, lunar sample analyses, the recovery of the Old Woman meteorite and recovery of thousands of meteorites from Antarctica produced exponential growth of the collection. The collection today serves as the touchstone by which samples returned by spacecraft are interpreted.

The Smithsonian Institution's meteorite collection traces its roots to England in the last decades of the 18th century, and to the Institution's founder and first meteorite collector James Smithson (*c*. 1765–1829).[1] The United States first learned of Smithson when the *New-York American* of 26 January 1830 reprinted a story from *The Times* of London of 10 December 1829. It reproduced Smithson's will, which was in probate court, and noted that under 'certain circumstances' his estate would come to the US. The 'certain circumstances' – the death of Smithson's nephew without progeny – came to pass, and in 1835 the British Government officially informed the US of Smithson's death and of the strange, last-resort provision of his will that had come into force: 'I bequeath the whole of my property to the United States of America, to found in Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men'. The US Congress accepted the bequest from this unknown benefactor, and envoy Richard Rush (1780–1859) was sent to London to see the matter through Chancery Court. In 1838 a fortune of more than $500 000 in gold, Smithson's mineral collection (containing a suite of meteorites), some of his personal effects, his books, and over 200 manuscripts, letters and notes arrived safely in Washington.

Congress debated at length the nature of the 'Institution' to be formed, and it was not until 1846 that the Smithsonian Institution was created by an act of Congress. The distinguished physicist Joseph Henry (1797–1878) was appointed its founding Secretary and assumed responsibility for creating a new type of organization. The Smithsonian Institution Building (now generally known to the public as the Castle) was constructed on a site that is now on the National Mall, and was occupied by the mid 1850s. These early years were troubled for the Smithsonian Institution due to competing interests, lack of established precedents and the advent of a brutal Civil War. As the war was winding down in early 1865, the Smithsonian Building was severely damaged by fire. Smithson's mineral collection, his manuscripts and his personal effects were lost. A rich and untapped

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0305-8719/06/$15.00

resource of the Institution's founder, a man unknown in the US, was gone.

James Smithson the scientist

James Smithson (Fig. 1) was illegitimately born of a union of two illustrious English families, and he was known as James Lewis Macie until 1801.[2] As a well-educated young man – MA 1786, Pembroke College, Oxford – he began his lifelong pursuit of mineralogical and geological knowledge and specimens. A talented blowpipe analyst, he appeared on the scientific scene with interests, skills, dedication, personal connections and financial resources that enabled him to become a respected contributor to the science of his era. His 10 000 specimen mineral collection that arrived in Washington undoubtedly included among its suite of meteorite specimens representatives of those particularly provocative European falls of the final years of the 18th century and very early 19th century.

The loss of Smithson's archive and mineral collection brought home to Smithsonian Institution officials how little they understood of the character and accomplishments of their benefactor. Chief Clerk William J. Rhees (1830–1907) searched Smithsonian Institution records for

Fig. 1. James Smithson (*c.* 1765–1829), from a miniature portrait done from life in 1816 by H. Johns. Courtesy of the Smithsonian Institution Archives, R.U. 95, Box 21.

information on Smithson and published it along with extant published reports (Rhees 1879, 1880). Smithson's 27 scientific papers are included, as is an informative report by W.R. Johnson (1844), 'A memoir on the scientific character and researches of James Smithson, Esq., F.R.S.'. Johnson had full access to Smithson's Washington material before the fire, and his paper makes clear the historical richness of the Smithson deposit as it arrived from Great Britain.

Smithson's first recorded scientific adventure was as a participant at age 19 in the well-known and, in part, rigorous Faujas de Saint-Fond trip to Scotland and the Isle of Staffa in 1784 (Geikie 1907). This was arranged by an Oxford mentor, William Thomson (1760–1806).[3] After leaving Oxford, Smithson spent a period in London where he was sponsored by Henry Cavendish (1731–1810) among other prominent savants, and had access to Cavendish's personal laboratory and library. He attended Royal Society meetings and was elected a Fellow in April, 1787, one of the youngest individuals ever to receive this honour. It is clear that he was a highly respected young man dedicated to science generally, and particularly to mineralogy and mineral analysis.

By late 1791 Smithson was living in Paris. On 1 January 1792, he wrote to his London friend Charles Greville (1749–1809) expressing satisfaction with the Paris winter, the early stages of the French Revolution and metaphorically compared the Revolution to the then erupting Mount Vesuvius, a geological interest of his. Anticipating spending the next winter in Italy, Smithson asked Greville for a letter of introduction to his uncle, Sir William Hamilton (1730–1803).[4] Hamilton was British envoy to the Court of Naples, and among his many interests he was an avid observer of the neighbouring Mount Vesuvius.

In the late spring of 1794 Smithson was residing in Florence and, if he had not already become aware of meteorites, his attention was about to be drawn to them in an exceedingly dramatic way. We surmise that at the time he was following Vesuvius's activity through correspondence with William Thomson, his former Oxford friend then living as an expatriate in Naples, some 200 km to the south. The volcano had been experiencing an unusually active period for some months. Thomson had taken on the recording of Vesuvius's activity as a major project and was collecting suites of specimens to document the flows, and particularly the interactions of lava with the materials it contacted, both natural and man-made.

On 15 June 1794, Vesuvius experienced one of its largest eruptions ever. Sir William Hamilton published an early report, and included in it a report of happenings 18 h later near Siena, a small town situated a little south of Florence (Hamilton 1795, pp. 103–105):

> I must here mention a very extraordinary circumstance indeed, that happened near Sienna [*sic*] ... about 18 hours after the commencement of the late eruption of Vesuvius ... although that phaenomenon [*sic*] may have no relation to the eruption: ... 'In the midst of a most violent thunder-storm, about a dozen stones of various weights and dimensions fell to the feet of different people; the stones are a quality not found in any part of the Siennese territory; ...'.

We are indebted to the recent investigations of Smithson biographer Heather P. Ewing[5] to learn of Smithson's reaction to these events and for permitting a quotation from her draft manuscript:

> ... Smithson immediately rode over the Chianti hills to Siena to see the fruits of the phenomenon for himself, according to a published account ... of the Siena meteor shower reads in parts like a fairytale, in the way it evokes Smithson's arrival, underscoring at the same time how heralded Smithson was among his scientific contemporaries in Italy: 'There was in this year also traveling in Tuscany the illustrious Chemist, J.L. Macie, [J. Smithson] whom I personally introduced to Father Soldani.' ... Smithson studied the stones that had been brought together and penned a description of his findings 'to his friend Mr. Cavendish' back in London, to spread the word of this extraordinary happening.

The fall of the Siena meteorite was well observed by Europeans from several countries and served to convince many of them of the reality of meteorite falls. Unfortunately, the Napoleonic wars interfered seriously with the general dissemination of these observations, resulting in the significance of the Siena fall not being generally recognized. In retrospect, however, it was this fall that initiated a period of transition from skepticism about meteorite falls to the modern view of their acceptance. Ten years later Thomson (1804) commented on this in footnote 3 of his paper on meteorite metal, the paper where the Widmanstätten pattern was first described. In recalling Father Soldani's contributions in reporting the Siena fall, he refers to Biot's report on the L'Aigle fall of 1803:

> a large number of observations seemed to be unknown or new at the time of the discussion that Mr Boit's report aroused in France ... The discussion of falling stones had already become outdated in Italy, even before it was taken up in France, for such is the limited nature of our communications.

Smithson was an active and respected participant in the community of scientists that laid the groundwork for modern meteoritics. He was personally acquainted with most of the scientists portrayed by Ursula Marvin in her study of Ernst F.F. Chladni and the origin of meteoritic science (Marvin 1996, 2006). To be sure, he was not a great innovator who passed on an important scientific legacy to following generations, but he was a respected and well-known member of his scientific community. His associates were the leading figures in science in the communities where he resided: London, Paris, Florence, Naples and several cities in Germany. It is safe to say that he knew, and was known by, the leading workers in mineralogy and mineral chemistry, his primary scientific interest, as well as in meteorite studies. His personal scientific contribution that is remembered today is his chemical study of the material then known as calamine and thought to be a single mineral. He showed that it actually consisted of two substances, the minerals known today as hemimorphite and smithsonite, the latter having been named in his honour (Smithson 1803). He also published on volcanic material from Mount Vesuvius sent to him in London in 1796 by William Thomson[6] in Naples (Smithson 1813).

The early Smithsonian Institution

The story of the Smithsonian Institution's early years is a rich historical feast in its own right, and much too complex to summarize here. Suffice it to say, museum-type activities were part of its programme from the beginning. The Smithsonian Institution took shape at a time when governments sponsored around-the-world exploring expeditions, and the US was sending expeditions and surveys into the American West. Collections of natural history, ethnological and archaeological specimens gravitated to Washington. The Smithsonian Institution could not avoid the responsibility of accommodating many of these collections.

An authoritative pictorial introduction to the Institution's early years, its people and its accumulating collections is provided by Field *et al.* (1993), and a brief history of the development of mineral sciences at the Smithsonian Institution by Mason (1975*a*). The 19th and early 20th century publications of the Smithsonian Institution and its several subunits are a rich source of historical information, as are the extensive collections of the Smithsonian Institution Archives.

Early meteorite activities at the Smithsonian Institution

As if in tribute to its founder, the first Smithsonian Institution meteorite studies were performed on James Smithson's meteorites. G. Brown Goode (Goode 1897, p. 305) set the scene by quoting from a report of the National Institute, the organization that had responsibility for Smithson's effects before they were moved to the new Smithsonian Institution Building in 1857: 'Among the effects of the Late Mr Smithson is a cabinet which, so far as it has been examined, proves to consist of a choice and beautiful collection of minerals... The cabinet also contains a valuable suite of meteoric stones, which appear to be suites of most of the important meteorites which have fallen in Europe during several centuries'. Secretary Joseph Henry's Annual Report for 1853 (Henry 1854) mentions their examination: 'The laboratory of the Institution during the past year has been used by Professor J. Lawrence Smith in the examination of American minerals. ... He also made a series of analyses of meteorites, among which were fourteen specimens belonging to the cabinet of James Smithson'.

Secretary Henry's report that Smith made 'analyses' of 'fourteen specimens belonging to the cabinet of James Smithson' is a claim that has been quoted in the context of actual chemical analyses. This, however, may be something of an overstatement. Smith published frequently and in full detail, with 40 mineralogical publications to his credit at the time, but there is nothing in his subsequent first meteorite paper or the many following meteorite papers that can be related to Smithson's meteorites (Smith 1855). His emphasis was American minerals and American meteorites. Smith's 46 meteorite titles (Silliman 1886) contain only one non-American name, Victoria West, Cape Province, South Africa. And Smithson's meteorites were known to have been European falls. A reasonable surmise is that Smith examined Smithson's meteorites visually, certified their legitimacy and reported his conclusions to Henry. Smithson's specimens must have been small in order for such a large number to be accommodated in his compact specimen cabinet. They would not have been attractive prospects for Smith to analyse chemically, even if permission could have been obtained to consume the required material.

By 1853 Professor J. Lawrence Smith (1818–1883) was a distinguished public figure, a Southerner, an innovative analytical chemist–mineralogist and a well-known mineral collector (Silliman 1886) (Fig. 2). He spent the year in Washington primarily for family reasons after having resigned his position at the University of Virginia. At the time he had no documented interest in meteorites. Whether this period in the Smithsonian Institution's Chemical Laboratory[7] was used to develop a latent interest, or whether his involvement with Smithson's meteorites awakened a new interest is not known. Whatever the stimulus, this was a turning point in Smith's research and collecting interests. With the exception of the Civil War years, when he was isolated and disheartened by what was happening in the country, his research and collecting energies were devoted largely to meteorites. The first of his many memoirs on meteorites was read before the

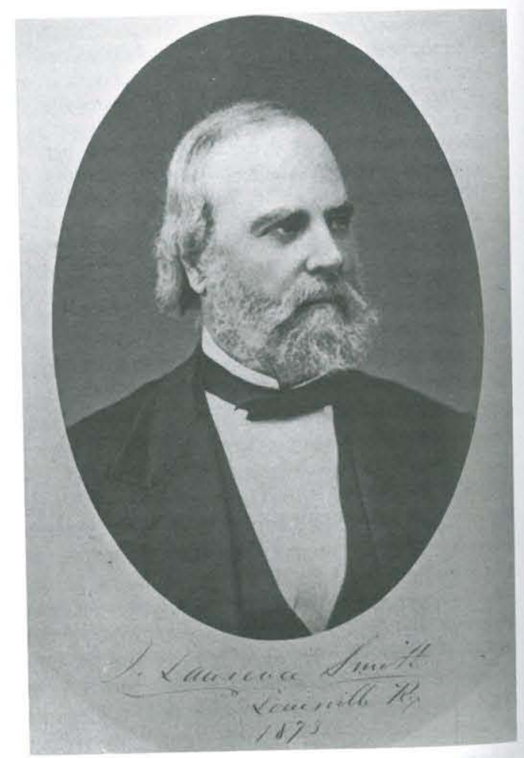

Fig. 2. J. Lawrence Smith (1818–1883), a mid-19th century mineralogist and chemist, analysed minerals and meteorites at the Smithsonian Institution in the mid-1850s. Later he became a serious meteorite collector and competitor of the leading meteorite collector of the period, Professor Charles Upham Shepard. Smithsonian negative number SIA 84-1108.

American Association for the Advancement of Science at their meeting at the Smithsonian Institution in April 1854 and published the next year (Smith 1855, 1856). Smith continued as a frequent correspondent with Secretary Henry over the years. Upon Smith's death his collection went to Harvard University, and his wife endowed the J. Lawrence Smith Fund at the National Academy of Sciences for support of meteorite research and the award of the J. Lawrence Smith Medal for outstanding contributions to meteoritics.

The Tucson, Arizona, Ring meteorite

The fact that the Smithsonian Institution had inherited Smithson's meteorites did not dissuade it from building a meteorite collection of its own. At least one major specimen, and possibly the first meteorite acquired by the Institution, was obtained prior to the 1865 fire. It is the Tucson, Arizona, Ring meteorite (Fig. 3), a specimen that ever since its acquisition has been iconic of our collection. The 688 kg Ring and its companion, the 287 kg Carleton piece, were both used as anvils in the presidio of Tucson while it was Mexican territory. US troops entered the area at the time of the Gadsden Purchase of 1853–1854, and US Army Surgeon Dr B.J.D. Irwin found the Ring abandoned in Tucson. Irwin had for several prior years served as a natural history specimen collector for Smithsonian Institution Assistant Secretary Spencer F. Baird (1823–1887). He contacted Baird about the Ring and found that Baird knew of the specimen and wanted it, and he made arrangements to have it shipped to Washington (Buchwald 1975). The story of the two Tucson specimens prior to the Anglos moving into Tucson, and the controversy and confusion that developed around moving them to Washington, is treated in interesting historic detail by Willey (1987). The Ring arrived at the Smithsonian Institution in 1863, was placed on exhibit immediately[8] and remained in the Smithsonian building, with the exception of a period when it was exhibited at the 1876

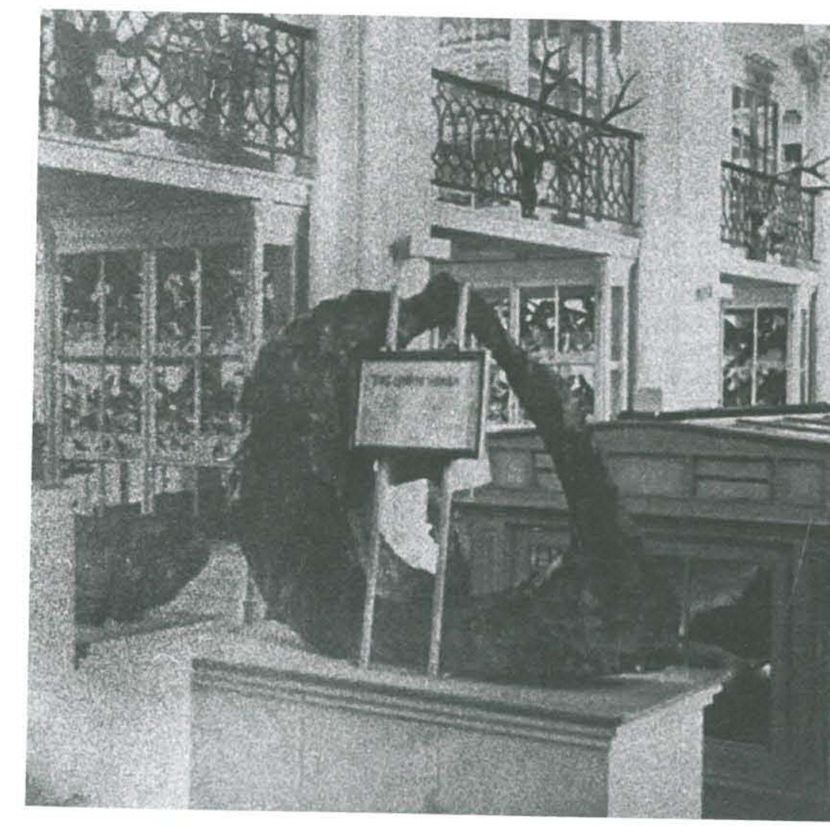

Fig. 3. The Tucson, Arizona, Ring meteorite displayed in the Smithsonian Institution building in 1863. This photograph dates from 1867. Smithsonian negative number SIA 87–5252–6.

Centennial Exposition in Philadelphia, until moved into the new US National Museum Building across the Mall around 1910, where it remains today.

Port Orford meteorite hoax

A very different type of long-term involvement with a problematic meteorite was initiated essentially simultaneously with J.L. Smith's work on meteorites at the Institution. John Evans (1812–1861), a contract explorer of the Oregon and Washington territories for the Department of Interior, collected geological specimens in Oregon in 1856. Three years later the Boston chemist Charles T. Jackson (1805–1880) recognized a pallasite meteorite specimen among samples Evans had sent him for analysis. Upon inquiry, Evans told Jackson that he had removed the small specimen from a 20 ton mass in the mountains near Port Orford, and the 'Port Orford meteorite saga' was initiated to unfold over 130 years of Smithsonian Institution history. A public campaign quickly developed to convince Congress to provide funding to retrieve the meteorite and bring it to the Smithsonian. Although this idea won surprisingly broad public support, the firing on Fort Sumter in early 1861, the resulting outbreak of Civil War and Evans' untimely death that year, made any such plan impossible (Burke 1986, p. 202).

The story receded into the background, but was revived in the early 20th century in the popular press. The press stories led to hundreds of failed attempts to relocate the meteorite over the years, and reams of frustrating official correspondence – especially at the Smithsonian after 1929 – when it obtained from the Boston Society of Natural History the small pallasite specimen that Jackson had called to scientific attention, which became known in the literature as the 'Port Orford' meteorite. The historical research of Plotkin (1993) and technical work of Buchwald & Clarke (1993) have demonstrated that Evans' discovery story was a hoax, and his 'Port Orford' meteorite was actually a small individual from the Imilac, Chile, meteorite, which he probably acquired while passing through Panama on his return from Oregon to Washington, DC.

Early growth of the collection

The first several decades of meteorite collecting at the Smithsonian Institution were haphazard, and surviving records include embarrassing lapses. An impression of early meteorite acquisitions may be obtained from entries in the master mineral catalogue prior to 1885. Three meteorites were catalogued in 1870, three listed in 1873, two in 1882 and nine in 1884, for a total of 17 specimens representing 13 different meteorites in 35 years of specimen accumulation. These results clearly indicate that prior to 1885 meteorites were valued when they came to the Smithsonian, but were not high-priority items. George P. Merrill (1854–1929) separated meteorites out of the mineral catalogue and entered them in a new meteorite catalogue around 1900. Currently, 15 of these early specimens are in the Smithsonian Institution collection, although several are reduced somewhat in size.

Enter F.W. Clarke

Spencer Fullerton Baird's elevation to the Smithsonian's second Secretary in 1878 provided the Institution with its first leader dedicated to the development of the US National Museum (Henson 2004). He visualized a museum organized along scientific-discipline lines and staffed well beyond the small number of current employees. Funds for new positions were not to be had, so Baird devised a creative solution. He appointed highly qualified individuals as Honorary Curators who assumed their responsibility with full authority and organizational support, but without pay. His choice for the Department of Minerals was Frank Wigglesworth Clarke (1847–1931),[9] the relatively young but already well-known chemist recently recruited by the US Geological Survey to the position of Chief Chemist (Fig. 4). Clarke was well known to the Smithsonian through its publication of three of his papers on the physical constants of chemical substances in the 1870s. During his decade of involvement with the meteorite collection the Smithsonian Institution published his revised and enlarged version of *The Constants of Nature* (Clarke 1888). Shortly thereafter he published his remarkably insightful paper, 'The relative abundance of the chemical elements' (Clarke 1892), the paper that set the stage for his classic *The Data of Geochemistry* that went through five editions over 40 years (Clarke 1959). Clarke served the Institution in this honorary position from 1883 to 1931, while simultaneously becoming a leading international figure in the development of chemical science and, in particular, geochemistry.

When Clarke arrived he was already a correspondent of Dr C.U. Shepard, Jr (1842–1915), an agricultural chemist who operated a commercial analytical laboratory in Charleston, South

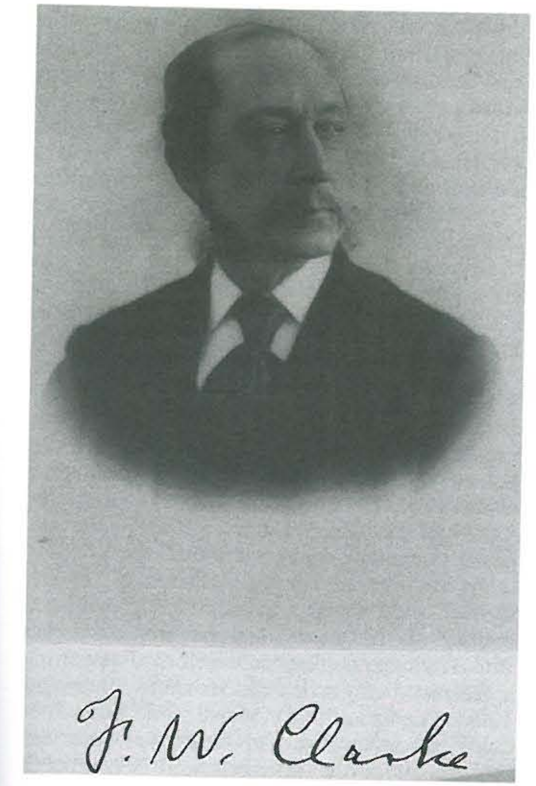

Fig. 4. Frank Wigglesworth Clarke (1847–1931), an international figure in chemistry and pioneering geochemist, set the pattern for the development of the Smithsonian's mineral and meteorite collections in the 1880s. Smithsonian Institution Archives RU7080, Box 1, F21.

Carolina, and was involved in phosphate mining and the development of mineral properties. Shepard's father, Professor Charles Upham Shepard (1804–1886), was an early and distinguished US mineralogist, and mineral and meteorite collector. Dr Shepard Jr shared his father's interest in minerals and meteorites, and by the 1880s was building his own meteorite collection with his father's and Clarke's help. Following Shepard Sr's death in 1886, his son deposited the Shepards' joint meteorite collection with the Smithsonian for public exhibit in recognition of his father's contributions to science. It was reported to be the largest meteorite collection in the country at the time. Clarke worked with Shepard[10] to continue the growth of both the Shepard and the Smithsonian collection through an active exchange programme. In May of 1888 Shepard wrote to Clarke saying that it was his intention to donate the collection to the Smithsonian Institution and that a clause to that effect had been written into his will. The status of the two collections as of 1888 is presented in detail in Clarke's meteorite collection catalogue (Clarke 1889). By then the Smithsonian had an internationally representative collection of over 250 specimens, mainly small but also containing several of major importance. It was augmented by the Shepard collection – which officially came to the Smithsonian in 1915 – of over 200 specimens. All in all it was a meteorite collection comparable to those in other major museums of the day. Clarke, a scientist of international stature and the first Smithsonian curator with a serious interest in building a meteorite collection, took meteorites at the Smithsonian Institution from curio status to a serious exhibit and research collection within a few short years.

The Merrill years

George Perkins Merrill[11] (1854–1929) joined the Smithsonian Institution in 1881, and during his 48-year tenure became a major figure within the Smithsonian and in US science generally. Brought to Washington by Assistant Secretary George Brown Goode, he developed rapidly into a multitalented scientist, museum administrator and writer. Merrill was productive from the beginning, and was appointed Curator in 1889 and Head Curator of Geology in 1896, a position he held until his death (Fig. 5). His early years were under the influence of F.W. Clarke, and he would certainly have been keenly aware of the Clarke–Shepard mineral and meteorite acquisition activity, and of the deposit of the Shepard meteorite and mineral collections at the museum (Roe 1975). Meteorite studies attracted his attention early, and in 1888 – the year of the Clarke meteorite catalogue – the first three of his approximately 80 meteorite papers were published.

Merrill arrived during the period that the Smithsonian was dealing with the many boxcar-loads of material that had arrived in Washington following the close of the Centennial Exposition of 1876 in Philadelphia. Specimens were being processed from storage into the then-new US National Museum Building (now known as the Arts and Industries Building). This was a difficult period[12] of insufficient staff, inadequate facilities, and frequent administrative and personnel changes.

Lacking support to continue his innovative studies of building stones in the 1890s, Merrill focused on meteorites and various aspects of their study. Meteorites were a major preoccupation for his remaining 35 years, and the collection grew steadily in both numbers and quality of

Fig. 5. George Perkins Merrill (1854–1929) in an undated photograph from about the time he became Head Curator of Geology in 1897. Among many accomplishments in geology and scientific administration, he became a leading meteorite authority and presided over the healthy growth of the meteorite collection for more than 30 years. Smithsonian negative number SIA 91-7251.

specimens. Representative material from virtually every important fall or find came into the Smithsonian collection. The Tassin (1902) catalogue documents the growth since the Clarke (1889) catalogue. Later Merrill's (1916) *Handbook and Descriptive Catalogue of the Meteorite Collections in the United States National Museum* continues in that vein and notes that the Shepard collection has been given to the Smithsonian. This catalogue also has an illustrated discussion of the classification of meteorites.

Much earlier Merrill had an experience that must have been formative in developing his interest in the full breadth of meteorite science. US Geological Survey (USGS) Chief Geologist, Grove Karl Gilbert (1843–1918), invited him to visit what we now know as Meteor Crater, Arizona, while he was conducting his investigation there in November 1891.[13] Enclosed with the invitation was a copy of W.D. Johnson's report on the crater that he had made at Gilbert's request (Davis 1926; Hoyt 1987). This was at the time that the Canyon Diablo meteorites and their proximity to an unknown crater structure had just been brought to public attention. Merrill had only published three meteorite descriptions, but he was a respected scientist associated with the Smithsonian's meteorite collection. His views would be of interest, as Gilbert considered meteorite formation of the crater as one possibility.

Gilbert's thoughts about the crater were discussed in many lectures in the late 1890s and early 1900s, and his conclusion appeared in print in his famous 'The origin of hypotheses ...' paper (Gilbert 1896). He concluded that Meteor Crater was formed by a volcanically induced steam explosion and not by meteorite impact, and the matter was never further discussed by him publicly. Such was Gilbert's stature and influence, particularly within the USGS at the time, that a pall was cast over crater studies for a number of decades.

A few years after Gilbert's paper, Daniel Moreau Barringer (1860–1929) obtained control of the crater, and he and co-worker B.C. Tilghman published their studies supporting a meteorite origin for the structure (Barringer 1905; Tilghman 1905). Merrill noted that suddenly an issue that had concerned few was brought to public attention and generated a great deal of interest. In May of 1907 Merrill returned to Meteor Crater for detailed fieldwork of his own that he published, by the standards of the day, in a lavishly illustrated review (Merrill 1908). While writing the paper in the fall of 1907 Merrill wrote to Gilbert about possible modes of its formation. In his response Gilbert expressed the view that a giant meteorite might have been causative:[14] 'It was kind of you to tell me the recent developments in regard to Coon Butte [Meteor Crater]. The evidence that Tilghman and you have gathered inclined me strongly toward the meteorite hypothesis, and I share your interest in the question: What became of the meteorite? ...'. Merrill understood that Gilbert's position was less firm than it had appeared in 1896. Unfortunately, Gilbert never expressed these views publicly, and Merrill felt duty-bound not to speak for him. The best he could do was to suggest rather clearly that Gilbert's views were really less firm than they had appeared (Merrill 1908, p. 488). The staunch believers of the dogmatic view of 1896 took no notice and continued to dismiss the possibility of meteorite formation for decades (see also McCall 2006*a*). The Smithsonian obtained important Meteor Crater specimens through these efforts, but D.M. Barringer was disappointed that Merrill had not taken a stronger stand. This did not help his business efforts to retrieve the large buried mass of Ni–Fe, but it did establish Merrill as a lifelong authority on the crater and its meteorites (see McCall 2006*a*).

While Merrill was building the meteorite collection, he was also active in disseminating information about the science of meteoritics – particularly the relatively new discipline of petrology. Smithsonian Secretary Joseph Henry had earlier recognized the lack of ready access for most US workers to European literature and Merrill faced this same problem. A number of important late 19th century meteorite papers – particularly those that were well illustrated – were published in very limited numbers. In contrast, Merrill's many papers, particularly during the early period, were published in the two most readily available US sources, the *American Journal of Science* and Smithsonian Institution publications. The Smithsonian Institution publications, in particular, offered an opportunity for a generous use of photographs, and Merrill was among the first US meteorite workers to use photographs to illustrate and introduce meteorite petrography to his readers. This trend culminated at the end of his career with the technical publication, *Composition and Structure of Meteorites* (Merrill 1930), and his book for the general reader *The Story of Meteorites* (Merrill 1929).

Another aspect of Merrill's career that was to have great importance for the development of the meteorite collection was his interactions with Harvey H. Nininger and Stuart H. Perry. Both of these men will be introduced in more detail later, but mention should be made here of their early contacts with Merrill.

H.H. Nininger (1887–1986) was a settled biology professor at McPherson College, Kansas, in 1923 when he happened on a paper on meteorites (Miller 1923). This was startling news to him that changed his life. He promptly became a serious meteorite collector, and soon a dealer and meteorite scientist. Nininger's early meteorite activities are documented in Smithsonian archives in the form of correspondence and transactions conducted with Merrill prior to the latter's death in 1929. Nininger found meteorite specimens but lacked the facilities to section them. Merrill provided this service with a promptness that could not be matched today, and with surprising generosity. The Smithsonian obtained parts of the sectioned meteorites for the collection, and Nininger obtained small pieces of meteorite that were available for trade or sale. In these lean times this service was of real importance to the development of Nininger's career in meteoritics.

Stuart Perry (1879–1957) was editor and publisher of the *Adrian Daily Telegram* – an Adrian, Michigan, newspaper – and an active meteorite collector and correspondent of Merrill's by late 1927. The two men developed a friendly relationship, and in a letter of 21 May 1928,[15] Perry explained why he was collecting meteorites. He was not collecting for frivolous reasons but to provide a good collection of meteorites to the University of Michigan, his Alma Mater to which he felt deeply indebted. A year later on 10 May 1929,[16] just 3 months before Merrill's death, he wrote stating a modification of his intentions: 'One of the things I wanted to say to you, and which I felt sure you would be glad to hear, is that I am going to give some of my meteorites to the Museum. This does not conflict with my original intention ... But in as much as the University of Michigan has made no special effort in their study ... Specimens of outstanding importance – more particularly undescribed meteorites – would better go to Washington'. Merrill must have been pleased with the promise, and he certainly would have been delighted by how it worked out many years later.

The final act

Merrill was on museum business in Europe during the summer of 1926 and received a welcome letter from Director Alexander Wetmore (1886–1978). It appeared almost certain that the Frederick A. Canfield (1849–1926) mineral collection and a generous endowment to maintain it were coming to the Museum. Merrill responded in a revealing letter from Paris on 14 August 1926:[17] '... while agreeably surprised it was not a 'bolt from the blue'. We – Foshag, Shannon and I – had often discussed our chances with Mr Canfield ... The deciding factor in the case was however, the high character of the work we have been turning out for some years past. Foshag & Shannon[18] have really 'put us on the map' ... and if we can once get good donations started our way I shall look for a continuance ... Now ... if we can but get the Roebling collection we will be on top of the world. I shall feel that my 40 yrs of museum work have resulted in something worth the while. You can, of course, not picture the condition of affairs when I began as Dr Hawes assistant in the summer of 1880, but I can, and I confess that I had begun feeling that matters here have not gone altogether to my liking'. The Canfield collection did come to the Smithsonian and was followed shortly by the magnificent Washington A. Roebling collection with a comparable endowment. It is the

Roebling Endowment, as discussed later, that came to play an important role in the development of the meteorite collection.

Merrill had achieved the highest recognition from his peers, with election to the National Academy of Sciences in 1922 and the award of that organization's J. Lawrence Smith Medal for his work on meteorites that same year. He died suddenly while on vacation in Maine in 1929, while he was still Head Curator of the Department of Geology. Merrill left a powerful legacy to meteorite science and to geological sciences in general at the Smithsonian Institution. By the time of Merrill's death in 1929, the modern museum structure had been formed and taken effect. We function today using contemporary versions of the patterns Clarke, Merrill and colleagues established in the late 19th and early 20th century.

The Henderson era

Edward Porter Henderson (1898–1992) began his long and distinguished career at the US National Museum in 1929, shortly after Merrill's death. His initial appointment was Assistant Curator in the Division of Physical and Chemical Geology in charge of the economic geology collections. With Merrill's passing, responsibility for the mineral collection fell to William F. Foshag (1894–1956), the Curator of the Division of Mineralogy and Petrology. One of Foshag's main duties was to organize the recently-acquired Canfield and Roebling mineral collections, and oversee their supporting endowments. Henderson helped in this endeavour, but his interest soon turned to the meteorite collection – probably because Merrill had earlier staked out meteorites as his personal purview and ornithologist Alexander Wetmore, the Director of the Museum, was now showing an active interest in them as well.

Henderson and Nininger

Shortly following Henderson's appointment, he found himself involved in dealings with Harvey H. Nininger (Fig. 6), who had recently given up his position as a biology teacher at McPherson College in Kansas, and launched himself on a career as the world's first full-time, self-employed meteoriticist. As this was clearly a risky undertaking in the Depression years, Nininger naturally worried if there would be adequate support for himself and his family.

Fig. 6. This photograph of Harvey Nininger (1887–1986) cutting a large meteorite with a band saw was taken some time after 1934, at the Colorado (now Denver) Museum of Natural History, where he held a staff position. Using this as a base of operations, he established the Nininger Laboratory, which became The American Meteorite Laboratory in 1937. Nininger had a long – and at times uneven – association with the Meteoritical Society, which he and Frederick Leonard founded in 1933. In 1967 he was awarded the Society's Leonard Medal. Photograph courtesy of Dr Carleton Moore, Arizona State University.

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A chance meeting with Wetmore, in Santa Fe in May 1932, provided Nininger with a golden opportunity to advance his cause, and he seized it. He informed Wetmore that he had definite information about four western meteorite falls, but lacked the necessary money to obtain them. If Wetmore was willing to provide him with $1000, he would be able to secure them, and would divide the specimens equally with him. Wetmore's interest was piqued, and on his return to Washington he carefully discussed this proposition with Foshag and Ray S. Bassler (1878–1961), the Head Curator of Geology. As a result, on 28 June 1932, an arrangement was worked out whereby the Smithsonian Institution agreed to pay Nininger $800 for 3 months of summer fieldwork.

Although Wetmore was used to, and comfortable with, the idea of the Smithsonian receiving specimens from collectors, using the Roebling Endowment to actively sponsor outside field searchers was a completely different kind of arrangement. For this reason, he felt a need to proceed cautiously. In a confidential letter to Henderson, who happened to be collecting minerals out west at the time, he asked him to check out Nininger. Henderson called on Nininger in September in Denver, where he had set up a base of operations at the Colorado (now Denver) Museum of Natural History. This meeting, along with a brief meteorite hunt they took together in the Utah mountains, afforded an excellent opportunity for them to get to know each other.

Within a short time, Nininger and Henderson began a lively exchange of personal letters – Henderson found meteorites interesting and enjoyed discussing them, and Nininger viewed Henderson as his best hope for Smithsonian contact at the working level. But the official correspondence with Nininger was handled through Foshag and Wetmore. Wetmore worked out an informal agreement whereby the Smithsonian agreed to purchase about $2000 worth of meteorites each year from Nininger from the Roebling Fund, so long as he could furnish meteorites needed for the collection at prices comparable to those charged by other dealers.

Over the next 2 years Henderson developed a noticeably increased interest in meteorites; by 1934 he had become a charter member of the Society for Research on Meteorites (the precursor of the Meteoritical Society), had published an article on two iron meteorites from New Mexico, had helped out in the curation of meteorites under Foshag's direction, and had been observing from the sidelines how Foshag and Wetmore were handling the Smithsonian's meteoritical dealings. In a move that exemplified his willingness and ability to take initiative (even, as we shall see, sometimes at the risk of overstepping his authority), he took the bull by the horns and, in September 1934, invited Nininger to discuss meteorite pricing directly with him.

By late 1937 Foshag had become deeply involved with the mineral collection and related fieldwork. Although he found time to carry out a few petrographic studies of meteorites, he was experiencing increasing difficulty in keeping up with the Smithsonian's day-to-day meteorite commitments. At the same time, it was clear that Henderson was showing a strong interest in meteorites, and was playing an increased role in dealings with Nininger. And so Nininger's first letter of 1938 to Foshag was given to Henderson for official reply. This marked a new course, and from this point on Henderson took over the management of Smithsonian Institution meteorite correspondence (Fig. 7). In several letters that year, Henderson complained to Nininger that his prices were too high, and that the specimens he was providing were ordinary weathered meteorites of no great scientific interest.

But there were larger issues at stake as well, which Henderson did not shy away from. For

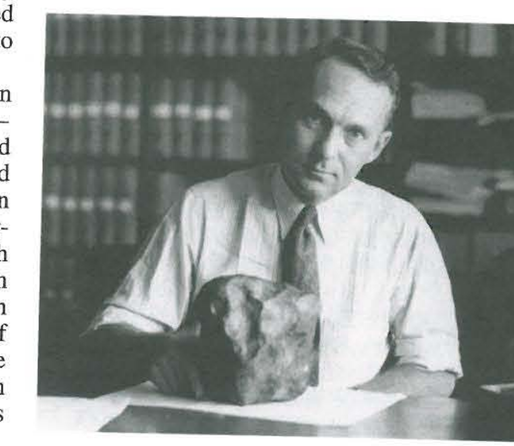

Fig. 7. The meteorite in this 1938 photograph, which appears to be a weathered ordinary chondrite, has so far eluded positive identification. Edward Henderson (1898–1992) played a major role in growing the Smithsonian's meteorite collection, and travelled throughout the US, Europe, the Philippines, the former Soviet Union and Australia hunting for specimens and arranging purchases and exchanges. During his tenure as Curator, he essentially doubled the size of the collection from about 550 to over 1000 distinct meteorites. Smithsonian negative number 95–1082.

example, he pointed out to Nininger that in purchasing meteorites from him, the Smithsonian was perhaps not acting in its own best interests: 'You are a collector and as one, are a competitor of ours'.[19] Although Henderson was willing to turn somewhat of a blind eye to this because he realized that Nininger and his family were living a precarious hand-to-mouth existence, he did not want concern for Nininger's external circumstances to override sound acquisition policy.

In memoranda addressed to Wetmore in April and July 1938, Henderson raised additional matters that were fundamental to Smithsonian policy. He pointed out that the Smithsonian meteorite collection was now large enough that it should be looking towards obtaining unusual and outstanding specimens, not the ordinary specimens Nininger had been offering, and towards obtaining major masses of meteorites in order to ensure future trade advantage. Furthermore, newly fallen meteorites would be preferable to the weathered ones Nininger was providing, which were often too weathered for satisfactory study.

Perhaps most crucial of all, Henderson questioned if it was really consistent with the Roebling bequest to spend major amounts of its income – earmarked expressly for the purpose of maintaining the mineralogical collections – to purchase meteorites (in some years, a quarter to a third of its income was being used for this end). And was it legitimate to use this bequest to hire an outside fieldworker to look for meteorites? These questions obviously opened Wetmore's eyes, for he immediately changed course and wrote to Nininger saying that Roebling Funds would no longer be available to support fieldwork. Henderson followed this with a letter in which he suggested that it might not be in the Smithsonian's best interest to continue to buy a set dollar amount of meteorites from him each year, and that it would henceforth only buy those specimens it considered both desirable and priced within its range.

Nininger feared that Henderson's raising of these issues might jeopardize his chances for future sales to the Smithsonian, and he indignantly wrote him threatening to 'henceforth cease to show any special favors to the U.S. Museum'.[20] In point of fact, however, Roebling monies continued to be used to purchase occasional meteorites from Nininger, simply because there were few other sources. But more thought and justification went into their purchase; the Smithsonian Institution's acquisition policy had taken a clear and highly constructive turn for the better.

Teetering on the edge of collapse, the Nininger–Smithsonian relationship soon totally disintegrated over events surrounding the recovery of the Goose Lake, California, meteorite. The story of this meteorite involves charges and countercharges, and is complex; only the main details will be given here. In March 1939 the Smithsonian learned from the US Forest Service that the previous October three deer hunters had discovered a 1167 kg iron meteorite on government land in the Modoc National Forest in NE California. The Museum informed one of the finders, Clarence Schmidt, that the Forest Service had authorized the Smithsonian to take ownership of the meteorite, and that he and the other finders would be given a suitable finder's fee.

Nininger heard about the meteorite in April, and harboured hopes that it might be on a parcel of private land in the National Forest owned by a lumber company. He quickly paid a visit to Schmidt in Oakland at the end of the month. Telling him he was a Smithsonian Institution 'Field Agent on Call' he asked to be shown the meteorite's location. Schmidt, who was expecting an as-yet unspecified Smithsonian representative to call, saw no reason to refuse this request, and agreed to it. Nininger didn't waste a second's time. They set out immediately for Alturas, their hopping-off point some 400 miles away, driving straight through the night to get there. After the meteorite was relocated, a survey determined that it was, in fact, located on federal land – by a margin of less than a quarter of a mile! – and the Smithsonian initiated plans to retrieve it (Fig. 8).

When Schmidt informed Henderson and Wetmore of Nininger's misrepresentation of himself as a Smithsonian field agent, they were furious. When Wetmore refused to reimburse Nininger for the survey he had carried out, the supposed insult was too much for him to bear, and he wrote blistering letters on 12 May 1939 to both Henderson and Wetmore. In his letter to Wetmore, he wrote: 'I feel compelled to say that much as I should like to go ahead on the arrangement we formerly made I consider it best to simply release you of any obligation . . .'.[21]

This effectively terminated the Smithsonian's 1932 agreement with Nininger. Wetmore shared Henderson's sincere concern for the well-being of Nininger and his family, and in his letter accepting Nininger's 'release' he reminded him that 'I am certain that the amount we have paid you in [past years] comes to a number of thousands of dollars'.[22] In fact, between 1932 and 1939, Nininger sold the

Fig. 8. Miss Barbara Rorig, the Secretary for the Division of Mineralogy and Petrology, and Edward Henderson with the Goose Lake meteorite on display in the late 1950s. In collaboration with Stuart Perry, Henderson made a special study of the large cavities in the meteorite. The results of their joint work, part of a larger study of seven iron meteorites, were published by the Smithsonian Institution shortly after Perry's death (Henderson & Perry 1958). The Goose Lake meteorite, with its unusual and enigmatic cavities, remains a popular Smithsonian exhibit. Smithsonian negative number 95–1081.

Fig. 9. With his strong technical background, Stuart Perry (1879–1957) was able to utilize metallographic methods that were well known in industry but which were largely ignored by meteoriticists. His use of a more accurate version of the iron–nickel phase diagram led to an understanding of the cooling rates of meteorites that enabled scientists to surmise the sizes of the meteorites' parent bodies. This line of research dramatically enlarged the horizons of meteoritics, and played a significant role in the birth of the new field of planetary sciences. Smithsonian negative number 95–1083.

Museum 102 specimens from 81 meteorites for a total of $9570 – a very considerable amount of money in those Depression days.

Henderson and Perry

At this critical juncture in the Smithsonian's meteorite programme, it fortunately was beginning to reap benefits from a different source – Stuart H. Perry (Fig. 9). The Museum's dealings with Perry offer a striking contrast to its dealings with Nininger.

As far back as 1927 Perry informed Merrill that he intended to donate some of the meteorites in his collection to the Smithsonian – particularly those he felt were either of outstanding importance or not represented in the Museum collection. But his intentions were not realized until 1935, however, when he donated a large specimen of the Paragould, Arkansas, meteorite (fall of 17 February 1930). In the transaction correspondence, Perry expressed the hope that the meteorite would be adequately described scientifically, and requested that the meteorite be appraised for tax purposes.

Having Perry become a benefactor rather than a competitor was most welcome, because the Museum at that time was still following Merrill's approach of writing to local postmasters when it heard of a new meteorite fall or find, and asking them to look into the matter on its behalf. Although this approach had worked well for Merrill, it was proving far less successful for Henderson; the Smithsonian was finding that Perry, with his instant access to ticker-tapes and his connections with newspaper reporters and editors, was routinely beating it to the punch, and Perry had already purchased a meteorite before the Museum had even heard about it. Foshag handled the curatorial aspects of Perry's donations and accessioned them into the Smithsonian collection, and Henderson provided the cutting and polishing services and carried out the chemical analyses of them.

Within a short time, Perry started corresponding with Henderson on the meteorites he was donating to the Smithsonian Institution. This led to a working relationship between them that developed into a collaboration on various research projects in the late 1930s – especially involving the metallography of meteoritic irons. As a result, Perry was appointed an Honorary Associate in Mineralogy at the Museum in April 1940, a position he held until his death. Perry and Henderson published a total of 16 collaborative papers, and came to develop a close personal relationship.[23]

Even though Perry had no formal training as a scientist, the technical education he received at the University of Michigan helped him to quickly develop considerable skill in his investigations. With Henderson's encouragement and help, he began to assemble a large collection of photomicrographs of iron meteorites for publication. Perry had highly talented graduate students at the University of Michigan prepare the metallographic sections and take the photomicrographs, and he carried on an extensive correspondence with Henderson about various chemical and metallographic issues. Although there was some serious soul-searching as to the appropriateness of publishing Perry's book at that time in view of the priorities brought about by the onset of the Second World War, *The Metallography of Meteoric Iron* was published by the Smithsonian Institution in 1944 (Perry 1944).[24] In 1945 Perry was awarded the National Academy of Sciences's J. Lawrence Smith Medal for meteoritic research (Henderson was later awarded this medal in 1970).

Perry always regarded the Smithsonian with great affection, and donated what he considered to be his most important meteorites – totalling 192 specimens – to it.[25] Although iron meteorites were his main interest and constituted the majority of his donations, one of the stones he donated – the Lafayette, Indiana meteorite – turned out to be not only one of the most exquisitely-oriented meteorites of the Smithsonian collection, but also one of its most valuable – it is a martian nakhlite. Building on the solid base established by Merrill's earlier accomplishments in meteorite research and acquisition, Perry's collaborative research with Henderson and his generous donations served to significantly advance the Smithsonian's meteorite programme. Within a short time, iron meteorites moved to a position of centre-stage, and they are still at the heart of the Smithsonian collection (Fig. 10).

Sale of Nininger meteorite collection

During the period between 1957 and 1965, several major interconnected-events took place that essentially laid the foundation for the future direction of meteoritics at the Smithsonian Institution. Perry died in 1957, following Foshag's death the previous year. In the autumn of 1957, Nininger came to the realization that the expenses of running his American Meteorite Museum in Sedona, Arizona, were greater than the income realized from admission charges and the sale of specimens and books. Now 70 years old, he turned his thoughts towards retirement but was concerned about his family's continuing financial well-being. After years of putting out feelers about the possible sale of his meteorite collection, he now decided that the time had finally come to do so.

Close to 20 years had passed since the events surrounding the Goose Lake meteorite episode and the ensuing break with the Smithsonian, but Henderson had kept in contact with him throughout the entire period, even purchasing meteorites from him from time to time. And despite obvious tensions and feelings of suspicion and mistrust on both sides, Nininger had sought Henderson's advice on various financial matters on several occasions. He often asked Henderson about the advisability of breaking up his collection and selling it piecemeal, but Henderson consistently urged him not to do so. Nininger had always claimed that he considered the Smithsonian as the logical place for his collection to end up, and, now that he was finally going to sell it, Henderson wanted to insure that it did, in fact, go there.

Nininger's asking price was $200 000. Henderson felt that the price, although high, was fair and reasonable, but fearing that it was more than the Smithsonian could manage he turned to the National Science Foundation (NSF) for funding. Before submitting a formal proposal, he decided to seek letters of support from eminent scientists outside the Museum.

The scientists he turned to were using meteoritic material from the Smithsonian collection in cutting-edge research. In the years following the Second World War, advances in fields allied to meteoritics – such as atomic physics, X-ray crystallography and spectroscopy, and chemical thermodynamics – transformed that science completely. Although Henderson's training did not allow him to fully-understand the nature of this new research, he intuitively

Fig. 10. The three large irons in the foreground of this late 1940s photograph are Drum Mountains, Utah (which, as we discuss below, came to play a pivotal role in the legal case involving the Old Woman meteorite); Canyon Diablo, Arizona; and Owens Valley, California. The meteorite in the glass case immediately behind them is the Mount Vernon, Kentucky, pallasite. On the back wall a large map of the United States shows the locations of all of the nation's known meteorite falls and finds. Smithsonian negative number 37–287-F.

realized the importance of the advances being made and wanted the Smithsonian to be in the forefront of these exciting new developments. The best way he could support this research was to generously supply the meteoritic material necessary for these studies. In sharp contrast to most meteorite collection curators of his day, he – along with Brian Mason, then at the American Museum of Natural History – devoted tremendous energy to providing scarce specimens from the Smithsonian's collection to worthy outside investigators (Henderson jokingly referred to his desk as the 'Gift Package Desk').

The list of scientists who provided strong letters of support for the Smithsonian's proposal reads like a 'Who's Who' of the scientific elite of the day, including: Alfred Nier (1912–1994), University of Minnesota; Fred Whipple (1906–2004), Smithsonian Astrophysical Observatory; Harold Urey (1893–1981), University of Chicago; Harry Hess (1906–1969), Princeton University; Harrison Brown (1917–1986), California Institute of Technology; Edward Teller (1908–2003), University of California; Thomas Nolan (1901–1992), US Geological Survey; and W.F. Libby (1908–1990), Atomic Energy Commission.

But before the Smithsonian submitted the proposal to the NSF, it received some very troubling news in March 1958: Gavin de Beer (1899–1972), Director of the British Museum, wrote to Smithsonian Institution Secretary Leonard Carmichael (1898–1973) that Nininger had offered his Museum roughly half of each fall represented in his collection for $144 000. As he felt the two institutions should not bid against one another, he asked Carmichael to inform him of the status of the Smithsonian negotiations.

Henderson had realized that there might be competition from the British Museum. A year earlier he had learned from Max Hey (1905–1984), the Keeper of Minerals there, that Nininger had tried to interest the British Museum in purchasing his collection. But a telegram from Nininger on 2 April 1958 put Henderson's fears to rest: 'Would be great inspiration to see collection go to National Museum. It is primarily a collection of North American falls and should remain in U.S . . . '.[26] On 16 April the Smithsonian proposal was formally submitted to the NSF.

By the end of May Henderson informed Nininger that, although he had not received official notification from the NSF yet, he was very optimistic that approval of the Smithsonian proposal would be forthcoming in early June, and that funds would be available some time after July. But to his profound disappointment, he received a letter from Nininger on 17 June informing him that he had accepted the British Museum's offer on the 'vertical split' they had requested, and that no further sales would now be contemplated.[27] It was a dark day for Henderson and Smithsonian officialdom, who felt betrayed. The initial Smithsonian response was one of overreaction. Led by A. Remington Kellogg (1892–1969), Acting Director of the Museum, various ways of stopping the exportation of the material to England were explored.

Henderson had been suspicious of the Smithsonian's overreaction from the start and realized that Nininger had cut what he considered his best deal. He therefore accepted this, and now turned his efforts towards the possibility of acquiring the remainder of his collection (the sale to the British Museum was for less than one-third of the original collection). Receiving assurance from the NSF that the Smithsonian's original proposal could be reactivated, in December 1959 he wrote to the scientists he had written to earlier, and asked them if they would send him a new letter endorsing such a plan. Henderson was anxious to succeed, because he had learned that Nininger had approached Arizona State University (ASU) about purchasing the remainder of his collection.

Nininger apparently wanted his remaining collection to stay in the west, so it would be near Meteor Crater, and was annoyed with the Smithsonian's clumsy attempt to block the export of his sale to the British Museum. As a result, he offered it to ASU for a price 'many thousands of dollars less' than he offered it to the Smithsonian. But as ASU could not afford the purchase outright it, too, sought acquisition funding from the NSF. While this negotiation was taking place, in the spring of 1960 Nininger let it be known that he was thinking of taking his collection to Europe to try to sell it there. Whether this was purely a bluff or not, the NSF feared that the remainder of his collection might also end up leaving the country, and quickly granted ASU its request.

In explaining the history of these events to Secretary Carmichael, Henderson expressed a fear that the ASU collection, which had been purchased through federal funds and was to be supervised by a committee of meteorite and museum experts, might well become better outfitted than the Smithsonian to handle meteorites: 'Thus, it will become the second national collection and take the lead from us'.[28] This was a very serious concern, one that the Museum could not ignore.

National Museum of Natural History (NMNH) and the Smithsonian Astrophysical Observatory (SAO)

At the same time that the National Museum of Natural History (NMNH) was facing this threat from the west, it also began to face one from the north, from the Smithsonian Astrophysical Observatory (SAO). The SAO had moved from Washington to the grounds of the Harvard Observatory in Cambridge, Massachusetts, in 1955, and Fred L. Whipple was appointed as its first Cambridge Director. Under his direction, the SAO quickly became a major centre for solar system research, and large-scale interdisciplinary projects were begun on several fronts. Researchers trained in fields other than astronomy were hired to carry out these projects, including physicist Edward Fireman (1922–1990), ballistics researcher John Rinehart, geologist Ursula Marvin and geochemist John A. Wood. With strong interests in upper atmosphere, solar system and comet studies, Whipple increasingly began to focus his research on meteors and meteorites. Fireman established a laboratory in 1956 to measure cosmogenic isotopes, and to determine exposure ages measuring ^{39}Ar to ^{37}Ar ratios. Whipple felt a need for larger amounts of meteoritic material, especially newly fallen meteorites, for Fireman's studies of cosmic-ray exposure ages.

Whipple was comfortable with, and had great success in writing, grant proposals for big projects involving large sums of money, and quickly drew up a proposal for 'Photographic Observation of Meteorites-in-flight and Their Subsequent Recovery' and sent it to Secretary Carmichael for approval. Carmichael, who strongly wished to support his recently appointed SAO Director and his Cambridge set-up, quickly signed-off on it and forwarded it on.

The majority of the funds Whipple sought was for the establishment of the Prairie Network – a network of meteor cameras that would automatically and continuously photograph the night sky over a large area of the midwest US. But as it was projected that this photographic patrol would lead to the recovery of meteorites, Whipple's proposal would have the SAO take over a role that had traditionally been served by the Smithsonian Institution's NMNH, which had become a separate administrative entity in 1957 when the US National Museum was divided into the NMNH and the Museum of History and Technology. This led to serious strains between the two branches of the Smithsonian over the acquisition and control of meteorites.

Throughout the last half of 1960 and all of 1961 Henderson campaigned vigorously and tirelessly on behalf of the NMNH, writing to the same group of scientists, among others, whom he had earlier written for support in his effort to acquire the Nininger collection of meteorites. They strongly supported the NMNH as the proper collecting agency, repository and distribution centre for meteorites. Edward Anders of the University of Chicago typified their sentiments: 'I have always felt that the National Museum is the most appropriate repository for meteorites, not only because it is a national institution, but also because the Curator, Ed Henderson, has been extremely generous and sensible in distributing meteorites to qualified researchers'.[29] Clearly, Henderson's outstanding job of curating the national collection and his generous policy of providing outside investigators with meteoritic material for their studies had won the NMNH many loyal and strong friends. A memorandum from Assistant Secretary James Bradley (1910–1984) and Kellogg in December 1961 settled the jurisdictional dispute in favour of Henderson and the NMNH.

Expanding meteoritics at the NMNH

By now top Smithsonian administrators had been forced to come to the realization that the meteorite programme at the NMNH had to be strengthened considerably if it was to compete successfully with the new programme at ASU and Whipple's programme at the SAO, and become a world-class centre. Events surrounding Henderson's efforts in the retrieval and distribution of a meteorite that fell in Texas in May 1961 forcefully drove this point home.

On 30 May 1961 an 18 lb meteorite fell in Harleton, Texas, and was recovered within hours. As was his usual custom, Henderson immediately travelled to the fall site to try to arrange for its purchase. Because the landowner wanted more money for a finder's fee than Henderson thought the Smithsonian could supply, he quickly made an arrangement with five institutions to help in its purchase (the Brookhaven National Laboratory, the University of Chicago, the University of Kentucky, the Carnegie Institute of Technology and the University of California, La Jolla). Collectively, they would pay the lion's share of the meteorite and would receive generous portions for their research, but the NMNH would accession it as part of its collection.

As it was imperative to get samples to researchers quickly in order for them to perform isotopic studies, Henderson didn't hold matters up by following standard Museum procedures: 'I have violated all the rules of the Museum concerning the dispatch of material . . . I am now in the DOG HOUSE'.[30] Within a week the Director of the NMNH, Albert C. Smith (1906–1999), issued Henderson a stern memorandum outlining his breach of procedure. Copies of the memorandum were sent to several senior Smithsonian Institution officials, and one was placed in Henderson's personnel file.

G. Arthur Cooper (1902–2000), Head Curator of the Department of Geology, quickly and forcefully came to Henderson's defence. In a memorandum to Bradley, he argued that as the meteorite had not yet been officially accessioned, it was not government property when Henderson sent out specimens. Under these circumstances he had not breached Museum rules, and the memorandum should be withdrawn from his personnel record. Cooper went on to praise Henderson, and voiced his absolute confidence in him: 'I have not met anyone in the Smithsonian who is so wholeheartedly devoted to its interests as Mr Henderson. I think that much of the great value of this collection and its large size is due to his efforts and frequent personal sacrifices . . . It seems to me, therefore, that we must get together and find a way by which we can more adequately assist Mr. Henderson in his good work'.[31]

Bradley regretted the 'misunderstanding' surrounding Smith's memorandum, and pledged Cooper his full co-operation, but did not withdraw the memorandum. But it did serve to drive home the point that the Smithsonian's meteorite programme was facing severe problems, and ways had to be found to strengthen both it and Henderson's role as Curator. There can be little doubt that this consideration played a key role in his decision (with Kellogg) a few months later favouring the NMNH in its dispute with the SAO.

It was one thing for Cooper to help out in a particular matter such as this, but there was still the larger problem of how the current situation in meteorites could be strengthened. A possible solution was suggested by George Switzer, Curator of the Division of Mineralogy and Petrology, who suggested dividing the Department of Geology into a Department of Palaeontology and a differently structured Department of Geology, which would include a Division of Meteorites.

The idea appealled greatly to Cooper. In his Annual Report for 1960–1961, he claimed that such a division would not only be an effective way to hire sorely needed palaeobotanists, but would also be a way to increase the level of support for the mineralogists, who needed more money for equipment. And he was quick to point out that the creation of a Division of Meteorites would strengthen that programme, and would be an effective way of preventing ASU from becoming a second national collection that might eventually eclipse that of the Smithsonian.

Cooper proposed the idea to Bradley. As Assistant Secretary, Bradley was responsible for the administrative, fiscal and legal planning for the Smithsonian, and worked on key issues for Secretary Carmichael. Although he often operated behind the scenes, it is clear that in a very real sense he was the power behind the throne. He quickly lent his support to Cooper's reorganization proposal, and took it under his wing. On 15 October 1963 the reorganization plan officially went into effect, and the former Department of Geology was divided into two new departments: a Department of Mineral Sciences (which contained the new Division of Meteorites) and a Department of Palaeobiology.

Bradley's efforts to strengthen the meteorite programme did not end here. In 1963, while Henderson was in Australia doing fieldwork with Mason, Bradley worked closely with Cooper and Roy S. Clarke, Jr to help facilitate the Smithsonian's purchase of the Arthur R. Allen meteorite collection through an addition to the National Aeronautics and Space Administration (NASA) grant NsG-71-60. Clarke had joined the Smithsonian Institution as a chemist in 1957, but did not get seriously involved with the meteorite programme until 5 years later. By then he had met Nininger and Peter Millman (1906–1990), the President of the Meteoritical Society, and had attended his first Society meeting; within a short time meteorites became his main research area and passion.

Bradley also worked closely with Henderson in his efforts to put together a proposal for a much larger NASA grant. As early as October 1962 Henderson had prepared a draft of a 'Meteorite Research Proposal' for sorely needed additional staff and equipment – especially an electron microprobe. He felt that without one, the NMNH ran the danger of simply becoming a service centre for the distribution of its material to outside scientists for their researches.

When Henderson discussed his proposal with Smithsonian administrators, Bradley suggested that the 'proper man' to run the microprobe (i.e. a first-rate research scientist) should be in place before submitting it. He further said he was willing to upgrade a currently vacant position to a level that would attract such a person. Henderson was one step ahead of Bradley here; as early as February 1962 he had been carrying on correspondence with Kurt Fredriksson (1926–2001), of the University of California, La Jolla, about the possibility of him coming to the Smithsonian to establish an electron microprobe laboratory at the NMNH. Thinking big, Henderson hoped that he might be able to also get Klaus Keil, who was then at the University of California, San Diego doing collaborative microprobe work with Fredriksson.

With Secretary Carmichael's blessing, the completed proposal, 'Studies of Constituents, Compositions, and Textures of Meteorites, and Their Bearing on Theoretical Problems', was submitted to NASA on 20 June 1963. The proposal included requests for funds over a 3 year period for three new scientists, two more technicians, an electron microprobe and the acquisition of meteorites.

One year later, on 9 June 1964, the Smithsonian received word from NASA that its requested grant had been approved (NsG-688). Funds for the first year enabled Fredriksson and a technician to come to the NMNH that August, the microprobe to be purchased, and new staff to be added. Chemist Eugene Jarosewich joined the meteorite group that November. Brian Mason, who had carried out fieldwork in Australia with Henderson collecting meteorites and tektites in 1963 and 1964 (as well as later, in 1965 and 1967), joined the NMNH in March 1965.[32]

Henderson, who had advanced to Curator-in-Charge of the Smithsonian meteorite collection, officially retired on the last day of 1965, but stayed on as a Research Associate and continued to maintain an active presence in the Division of Meteorites until the mid-1980s. Although he was innovative in his approach to collection growth, his 58 published papers on meteoritics were mainly devoted to matters of description and classification, and, like those of many other investigators of his day, were workmanlike in nature. Following a period of declining health and incapacity, he died on 12 September 1992. In many ways he was a businessman at heart, and decided long before he retired to endow the Smithsonian's meteorite collection. His programme evolved over the years, and came to also include his wife's estate. The Smithsonian Institution's Edward P. Henderson and Rebecca Rogers Henderson Meteorite Fund has been providing modest support for meteorite acquisitions and related activities in recent years, with a larger yearly income becoming available in the near future.

Meteoritics since 1969

By the end of the 1960s, the Smithsonian had achieved a leadership position in the field of meteoritics, with a strong combination of personnel and equipment, facilitated by NASA funding for the soon-to-be-return of lunar samples. Brian Mason was probably the most prominent meteoriticist at the NMNH among a group that included: Kurt Fredriksson, who was largely responsible for the electron microprobe; Roy S. Clarke, Jr, who soon succeed Edward Henderson as Curator of the meteorite collection; Eugene Jarosewich, who achieved prominence in the chemical analyses of meteorites; and Robert Fudali, an experimental petrologist who would play a role in the Smithsonian's involvement in Antarctic meteorites. The growth of the collection itself was impressive up to this point. Having grown from a handful of meteorites in the 1880s to 767 distinct meteorites in 1948 (Henderson 1949), the collection stood at more than 1000 distinct meteorites by 1969.[33] Much of this growth occurred late in the 1960s, with acquisition of the extensive mineral and meteorite collection of the late Nobel-laureate Carl Bosch and the transfer of an extensive, and largely-orphaned, meteorite collection of the University of Minnesota. As of 1 January 1969, 3470 accessions had been made to the collection, probably representing 4000–5000 individual specimens.

The year 1969 was truly a remarkable one in the history of meteoritics. The landing of *Apollo 11* on the Moon that year marked a turning point for all of planetary sciences. For the first time, extraterrestrial materials arrived not by random chance, but as the result of exploration of another world. There is no question that this pivotal event shaped the Division of Meteorites, but it was only one of several events that occurred in 1969 that would eventually reshape the future of meteoritics at the Smithsonian Institution. The first significant event was the fall of thousands of stones from the Allende meteorite on 8 February 1969, in Mexico. On 20 July of that year, humans first stepped onto the surface of another world, our Moon. On 28 September another huge shower of stones fell at Murchison, Victoria, Australia. Together, Allende and Murchison came to redefine our view of the early solar system. The changes resulting from their fall continue to be felt in meteoritics into the 21st century. Perhaps the most significant event of the year and the one with the greatest long-term impact was the least recognized at the time. On 21 December 1969, a group of Japanese glaciologists discovered nine meteorites in Antarctica (see Kojima 2006).

The Allende meteorite

The fall of the Allende meteorite in February of 1969 led to a profound growth of the meteorite collection and had far-reaching implications for the direction of research at the Smithsonian. Mason and Clarke travelled to Mexico within days of the shower (Clarke *et al.* 1971*a*) to recover material, and additional searches by Clarke and Jack Hyde of the Smithsonian Astrophysical Observatory's Prairie Network Meteorite Recovery Project took place over the course of the next year (Fig. 11). In total, 1830 individual stones were acquired by the Smithsonian through a combination of fieldwork and purchases funded by a NASA grant. From this single event in early 1969, the Smithsonian acquired nearly half as many individual specimens as had been acquired in the previous century of collecting.

While Clarke generously allocated material to 37 researchers in 13 countries around the world, the significance of this meteorite was not lost on the staff of the Division of Meteorites. Allende sample USNM 3529, a 35 kg specimen, received special attention. Shortly after the fall, Jarosewich powdered 4 kg to prepare the 'Allende Meteorite Reference Sample'. This sample has been analysed by hundreds of laboratories around the world (Jarosewich *et al.* 1987) and remains the only geochemical standard prepared from a bulk meteorite sample. It remains one of our most requested samples into the 21st century. One of the most striking features of Allende was the presence of centimetre-sized, white calcium–aluminium inclusions (CAIs; McCall 2006*b*). These CAIs had gained significant attention for mineralogies suggestive of high-temperature condensates and the presence of isotopic anomalies. Mason took advantage of the crushing of 4 kg of Allende by removing nearly two dozen large CAIs, which were mineralogically and geochemically characterized. Apart from the insights gained into CAI formation in the early solar nebula, this work provided a well-characterized set of CAIs used by researchers for decades to come. One of these researchers was Glenn MacPherson, then a postdoctoral fellow at the University of Chicago, who studied the petrology of calcium–aluminium

Fig. 11. Curator Brian Mason (centre), Gunther ('Skip') Schwartz of the Prairie Network's Lincoln, Nebraska, field station (left) and Charles Tugas of the Smithsonian Astrophysical Observatory (right) with a large mass of the Allende meteorite that Mason had just found in a nearby field, February 1969. Photograph by Roy Clarke.

inclusions. The influence of Allende continued, long after its fall, when MacPherson was hired in 1984 to fill the curatorial slot vacated by Mason's retirement, placing the Smithsonian at the forefront of a research discipline not even envisioned in 1969.

Lunar samples

Although the landing of *Apollo 11* on 20 July 1969, revolutionized planetary science, its impact on meteoritics at the Smithsonian was felt in subtle ways. It was, of course, the preparation for the lunar landings that brought both NASA-funded personnel and equipment to the Museum beginning in 1965 and set the stage for its involvement in a wide range of research topics. The lunar rocks were, however, returned to NASA's Manned Space Flight Center (now Johnson Space Flight Center) in Houston, Texas, where they remain curated to this day. Thus, the addition of 381.7 kg of lunar samples by the six *Apollo* missions to the inventory of US Government-controlled extraterrestrial material did not add to the collections of the Smithsonian.

The lunar rocks did, however, greatly influence the research directions of those in the Division of Meteorites and, importantly, our exhibits. Mason, William G. Melson (appointed as Head of the Division of Petrology in 1964) and Fredriksson all became actively involved in the study of lunar samples, and published extensively on the subject from 1969 through to about 1975. Mason & Melson's (1970) book *The Lunar Rocks* was the first published scientific treatise on the geology of the *Apollo 11* samples. At the Smithsonian's Astrophysical Observatory, John Wood observed fragments of feldspar that he deduced must have originated in the lunar highlands, requiring a global magma ocean early in the history of the Moon. This intense period of study of lunar samples was particularly relevant in 1982, when Mason described the Antarctic meteorite ALH A81005 (Fig. 12) as containing clasts that 'resemble the anorthositic clasts described from lunar rocks'.[34] From his earlier work on lunar samples, Mason knew this was the first lunar meteorite, but presented his findings in a typically understated manner so as not to undercut the considerable research that would be forthcoming. Ultimately, the work on lunar meteorites opened the door to the recognition of meteorites from Mars.

The most striking change for the Division of Meteorites at the Smithsonian from the return of lunar samples did not reach fruition until the late 1990s. The geology hall 'Our Restless Earth' had opened in 1965, containing relatively little information about the Moon. At that time, the composition of the Moon was largely unknown and it was likened to both primitive carbonaceous chondrites and tektites. Indeed, the 1965-era exhibit contained a lunar globe with a blank far side, owing to the lack of any spacecraft images. The first lunar rocks displayed at the Smithsonian were at the National Air and Space Museum when it opened in 1976 with its still-popular lunar touchstone. Lunar rocks were not added to the displays of the NMNH – and then with little distinct focus on the history of the Moon derived from their study – until the late 1970s. This changed dramatically in 1996 with the opening of the Janet Annenberg Hooker Hall of Geology, Gems and Minerals (Fig. 13). Its display included spectacular lunar samples with text and artwork illustrating the geological history of the Moon, and the original lunar globe, now hung in its proper orientation, with the craters of the far side sculpted onto its once barren surface and the locations of the lunar landings prominently marked.

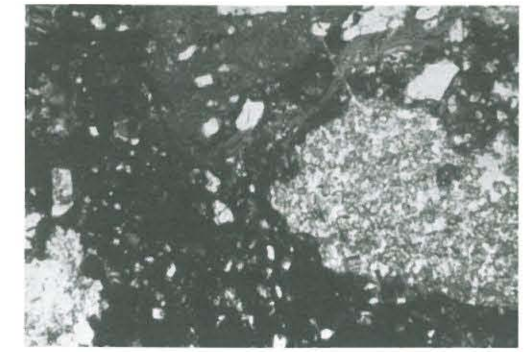

Fig. 12. Thin section photograph of ALH A81005, the first meteorite recognized to have originated on the Moon. The field of view is 1.5 mm in width. Photograph by Brian Mason.

The Murchison meteorite

While the fall of Allende and the lunar landings produced rather immediate changes in the collection and research of the Smithsonian, the events of the spring and autumn of 1969 would only influence the collection much later and, in many cases, were superseded by other events occurring between 1970 and 1976. As an example, the fall of Murchison (September 28, 1969, Victoria, Australia) was, in many ways, the antithesis of the lunar samples, having significant impact on our collections, but relatively little on our research or exhibits. NASA grant NGR 09-015-001(6313) provided the funds for purchase of nearly 200 individual stones from this shower of CM2 carbonaceous chondrite material. Murchison contained racemic mixtures of amino acids and aliphatic hydrocarbons, providing the first persuasive evidence that these were indigenous to meteoritic materials. Work over the next 20 years by others has identified

Fig. 13. Staff of the Division of Meteorites at the 1997 opening of the Hall of Geology, Gems and Minerals. Left to right: Curator Emeritus Roy Clarke, Postdoctoral Fellow Richard Ash, Chemist Emeritus Eugene Jarosewich, Curator Glenn MacPherson, Research Associate Bevan French, Collection Manager Elizabeth Scott, Curator Emeritus Brian Mason, Postdoctoral Fellow Sara Russell and Curator Tim McCoy. Photograph by Chip Clark.

more than 70 individual amino acids and redefined our thinking about early organic synthesis (see review by Cronin *et al.* 1989). At the start of the 21st century, with the renewed interest in astrobiology and the origin of life on Earth and Mars, Murchison remains one of our most valuable and requested samples.

The Lost City meteorite

On 3 January 1970, the Smithsonian Astrophysical Observatory's Prairie Network recorded the fall of the Lost City, Oklahoma, meteorite. Six days after its fall, the first stone – a 9.8 kg complete individual – was recovered and, in total, four fragments with a total mass of 17 kg were recovered (Clarke *et al.* 1971*b*). While Lost City was remarkable in being the only meteorite recovered by the Prairie Network and, at the time, only the second meteorite for which an orbit could be calculated, it is most noteworthy from our vantage point for the co-operation exhibited by NASA, the Smithsonian's Astrophysical Observatory and NMNH. Despite the infighting between these organizations around 1960, Lost City proved to be a model of co-operation between these agencies, with NASA providing funding, the Astrophysical Observatory operating the Prairie Network, and the NMNH distributing material to scientists and serving as the ultimate repository for the meteorite. As we discuss later in this chapter, this model of interagency co-operation would serve us well in later years.

The Old Woman meteorite

In February 1976 two prospectors found a 3 ton iron meteorite in the Old Woman Mountains of California (Fig. 14). A piece was first examined by the Museum in the late summer of 1976, beginning a 4 year odyssey that would become among the most controversial in the modern era of meteoritics at the Smithsonian. The story of the Old Woman meteorite has achieved something of a legendary status among meteorite hunters and collectors (see Norton 1994) and the complete story is beyond the scope of this paper. At its core, however, the issue of the Old Woman meteorite was a legal test over the ownership of meteorites, much of the history of which came from meteorites already held in the collections of the Smithsonian. As recounted by Schmitt (2002), the precedent that the land owner, rather than the finder, is the proper owner of meteorites found on that land was established by the case of Goddard v. Winchell before the Iowa Supreme Court in 1892. The

Fig. 14. Artist's rendering of the Old Woman meteorite as it occurred when found. Sketch by Marcie Dunn for the Smithsonian Institution.

meteorite in question was Forest City and the court held that the meteorite properly belong to the landowner Goddard. In 1967 this very specimen would be acquired by the Smithsonian as part of the transfer of the University of Minnesota collection. The acquisition of the Goose Lake meteorite by the Smithsonian from US Forest Service land was consistent with the earlier case. Thus, there was little legal question that the Old Woman meteorite, which was found on land controlled by the Bureau of Land Management (BLM), was the property of the US government.

Despite the clear ownership of the federal government, the meteorite was contested by the finders under a mining claim. Again, a meteorite within the Smithsonian's collection proved pivotal in the case of Old Woman. In 1944 Japanese-Americans interned in the Utah desert on federal lands discovered the Drum Mountains meteorite, which was ultimately acquired by the USNM. On 31 October 1944 the Assistant Secretary of the Department of the Interior responded to an inquiry by Henderson concerning the applicability of mining claims to meteorites. The Department of Interior reiterated its position that if meteorites have a market value only for the reason that they are meteorites, they are not subject to mining laws, citing the case of South Dakota Mining Company v. McDonald (30 L.D. 357) in which a mining claim was denied because the value of the land resulted solely from the presence of a cavern, not because of the presence of a commercially profitable mining deposit.

The final ruling in the Old Woman case was a consolidated ruling in a series of motions by the State of California and the San Bernardino County Museum against the Department of

Interior and the Smithsonian Institution to prevent the removal of the Old Woman meteorite from California. In its ruling, the US Court of Appeals for the Ninth Circuit affirmed a ruling of the US District Court for the Central District of California, which held that the Department of the Interior acted properly in transferring the Old Woman meteorite to the Institution under the powers of the Antiquities Act. Ownership of the Old Woman was transferred to the Museum in 1976. It was removed from the Old Woman Mountains by the Marine Corps in 1977 and spent a year on display in California. The meteorite first arrived in Washington, DC in 1978 and, after continued debate among interested scientists, the first large cut was completed in May 1980, revealing a complex internal structure transitional from a coarse octahedrite to a hexahedrite containing phosphide. The main mass was ultimately returned on loan to the BLM's Desert Resource Information Center in Barstow, California.

In the end, there was a certain irony when the internal structure was finally revealed. Ten years earlier, Clarke, who was at the apex of the Old Woman controversy, had begun a collaboration with Joseph I. Goldstein, then at Goddard Space Flight Center in Greenbelt, Maryland, and an expert on iron meteorites. Their collaboration ultimately led Clarke to earn a PhD with Goldstein as his advisor on the subject of phosphide growth and its influence on the formation of coarse-structured iron meteorites (Clarke & Goldstein 1978). Clarke received his degree from George Washington University in May of 1976, only a few months before the first, small sample of Old Woman reached the Smithsonian. While the acquisition of Old Woman remains a point of contention between meteorite hunters and the federal government, Old Woman served to reinforce the notion that meteorites found on public property rightfully belong to the people of the United States and should be available for research and exhibition through the Smithsonian Institution.

Antarctic meteorites

In most respects, the events of the last days of 1969 came to shape meteoritics at the Smithsonian more than any other single event in the previous 35 years. The initial discovery of Antarctic meteorites in 1969 (Kojima 2006, 295–6) was followed by extensive programmes sponsored by the governments of Japan, the United States (in collaboration with the Japanese initially), Europe (which sponsored EUROMET), Italy and China. The history of Antarctic meteorite collecting has been recounted elsewhere, most recently in a book by the US Antarctic Search for Meteorites (ANSMET) founder William Cassidy (Cassidy 2003). However, the role that the ANSMET programme would ultimately play in the growth of the Museum's meteorite collection has never been recounted.

The ANSMET programme began rather modestly in 1976 with the trio of Cassidy, Edward Olsen (Curator of Meteorites at the Field Museum) and Keizo Yanai (of the Japanese National Institute of Polar Research) recovering 11 meteorites. These meteorites were curated by Olsen at the Field Museum and pieces distributed in an ad hoc fashion to the research community. Despite the modest numbers for this joint US–Japanese team, it was clear that this was literally the tip of the iceberg and that large numbers of meteorites from the cleanest environment on Earth were soon to be recovered in Antarctica. An ad hoc committee was convened on 11 November 1977 in Washington, DC. The meeting included representatives of NSF (Mort Turner), the field party (William Cassidy), the Smithsonian (Brian Mason of the Natural History Museum and Ursula Marvin of the Astrophysical Observatory), NASA (Don Bogard of the Johnson Space Center and Bevan French of NASA Headquarters) and the scientific community (including Jim Papike). This meeting produced 'A plan for the collection, processing, and distribution of the US portion of the Antarctic meteorites collected during 1977–1978'.[35] However, much of the groundwork for this system of interagency co-operation (which ultimately was formalized as the three-agency agreement between NASA, the NSF and the Smithsonian Institution) and the distribution of samples was laid before the meeting. Brian Mason (pers. comm. 2004) recounted a conversation with Mort Turner expressing the opinion that meteorites collected by US field expeditions should properly become US government property. Mason also volunteered his services in the classification of meteorites. The three-agency agreement also calls for the Smithsonian to serve as the ultimate repository of the meteorites – a provision that would not be fully implemented for more than 15 years.

With nearly 30 years of hindsight, the formalization of the three-agency agreement was probably responsible for the long-term success of the Antarctic Meteorite Programme. The relationship has grown into one of mutual trust and respect among the agencies, and each is spurred by the other two to honour the terms of the original agreement. The spirit of mutual co-operation had not, however, always been the rule. Cassidy (2003) recalled his initial desire to form a curation centre for Antarctic meteorites at the University of Pittsburgh and described the intrusion of three leviathans in the form of the ultimate three-agency agreement. In hindsight, Cassidy agreed that the arrangement for curation and collection by NASA and the Smithsonian is probably the best possible arrangement.

From the Smithsonian Institution's perspective, the spirit of mutual co-operation between the field parties led by Cassidy and the Smithsonian was strengthened by the participation of several Smithsonian staff in the field efforts over the years. Ursula Marvin of the Smithsonian Astrophysical Observatory, who played a pivotal role in both the initial formation and long-term management of the programme over the next three decades, was the first Smithsonian participant in 1978–1979 and returned in 1981–1982, joined by Robert Fudali of the Division of Meteorites and a long-time associate of Cassidy. Subsequently, Fudali (1983–1984, 1987–1988), meteorite collection managers Twyla Thomas (1985–1986) and Linda Welzenbach (2002–2003), and postdoctoral fellows Sara Russell (1996–1997) and Cari Corrigan (2004–2005) served on the ANSMET field parties. It is interesting to note that as the programme evolved, the number of meteorites recovered changed dramatically. Starting with 11 meteorites in 1976, ANSMET averaged approximately 200 meteorites per year from 1976 to 1984, before ramping-up to an average of nearly 600 meteorites from 1985 to 2001 (Fig. 15). This average is remarkable given the cancellation of the 1989 field season due to logistical problems, and the intentional exploration of areas with greater and lesser numbers of meteorites to average out the curatorial workload from year to year. Very recently, NASA has supplemented NSF funding to provide a larger field-effort designed to increase the yield of martian meteorites, resulting in field seasons approaching approximately 1000 meteorites per year. It is, of course, too early to tell if this new growth is a long-term phenomenon. Nonetheless, the growth posed significant challenges for classifying this vast bounty of meteorites.

While the collection effort was shared by many, the classification of Antarctic meteorites was, at least for the first 20 years, largely the responsibility of a single individual, Brian Mason. In her oral history with Mason, Ursula Marvin (2002) recalls an early meeting with meteorite petrologist Klaus Keil, in which Keil expressed dismay at who would classify these vast numbers of stones, noting that neither he nor his students would be interested in such a task. The task had already been taken up by Mason, who had completed a description of a run-of-the-mill ordinary chondrite and provided the description to Marvin. Mason volunteered his services during the formative stages of the programme and it would be hard to have found a more perfect individual to undertake the challenge of classifying thousands of individual meteorites. During his tenure at the American Museum of Natural History in New York, and subsequently at the Smithsonian, Mason had examined virtually every type of meteorite known, pioneered the use of mineralogical data in the classification of meteorites in his seminal 1963 paper (Mason 1963) and, when faced with an unusual Antarctic meteorite, could quickly recall other similar meteorites he had examined during his career. During his long tenure with the ANSMET programme, Mason would go on to classify more than 10 000 individual meteorites, including a considerable number of Japanese meteorites during a visit to the National Institute of Polar Research in 1982. Many of these descriptions were compiled by Mason, along with co-editors Marvin and MacPherson, in five catalogs which were published between 1977 and 1987 in the *Smithsonian Contributions to the Earth Sciences* Series.

In the earliest days of the programme, a thin section was prepared of every meteorite and microprobe work conducted. As the numbers of meteorites ramped up between 1984 and 1988, it became clear that this laborious, time-consuming technique was producing an unacceptably large backlog of meteorites

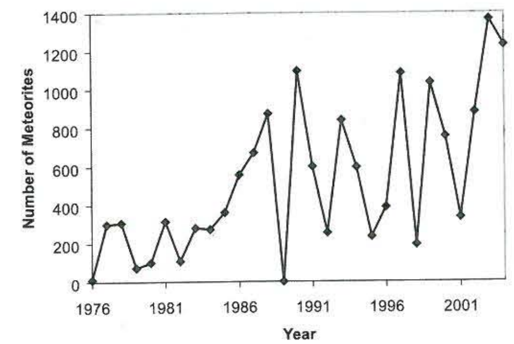

Fig. 15. Number of samples recovered by the Antarctic Search for Meteorites from 1976 to 1977 through the 2004–2005 season. The cyclical variation from 1989 reflects the choice of recovery sites and the abundance of meteorites recoverable at individual sites. The programme experienced significant growth between 1984 and 1989. In response to this growth, Brian Mason introduced the use of refractive index oils for classification of equilibrated ordinary chondrites. Recent growth has been spurred by additional funding from NASA to expand the collection of martian meteorites.

awaiting classification. Mason saw a need for a quicker technique to separate and classify the myriad of equilibrated ordinary chondrites. In 1987 he returned to one that he had successfully applied in the 1950s and early 1960s – oil immersion. The rapid determination of the composition of a few olivine grains from each meteorite became then, and remains, the method by which 80–90% of all US Antarctic meteorites are classified.

Mason counts among his most significant thrills in those years of classifying meteorites the identification of ALH A81005 as lunar (despite the cautious language he employed in the *Antarctic Meteorite Newsletter*[34]). This led meteoriticists to suspect that a number of other meteorites, including several from the Antarctic, were of martian origin. Interestingly, Mason played less of a role in these discoveries. Arch Reid of the University of Houston classified EET A79001 – from which the first definitive evidence for martian gases was found – and Glenn MacPherson classified the meteorites collected in 1984–1985, including the now famous ALH 84001. Mason never travelled to Antarctica as part of the field team. He was scheduled to go in 1977–1978, but an illness in the family prevented his participation. Although he retired from the Smithsonian in 1984, he continued in his role classifying meteorites for another 12 years. In 1996, on the heels of the retirements by Fredriksson in 1992, Clarke in 1993 and Fudali in 1996, the Division of Meteorites hired Timothy McCoy, in large part because of his experience and interest in classification and research on Antarctic meteorites. Ironically, McCoy, who would assume responsibility for the curation of the collection and classification of all Antarctic meteorites a few years later, was one of Klaus Keil's graduate students.

While Mason did the lion's share of the classification, Clarke and Jarosewich were intimately involved with the programme over a number of years. At the outset, NASA's Johnson Space Center recognized it lacked the equipment and expertise to curate iron meteorites and that task fell solely to Clarke. During his 25-year involvement in Antarctic irons, he recognized that nearly two-thirds were unusual in structure or composition, probably a result of sampling of unusual types by the very small irons (Clarke 1986). Jarosewich incorporated Antarctic meteorites into his long-standing programme of bulk chemical analyses of meteorites, producing both data and homogenized powders that may be used for decades to come.

The final obligation of the Smithsonian in the AMSMET Programme was serving as the long-term curatorial facility for specimens. This particular aspect proved to be, perhaps, the most contentious point of the Antarctic meteorite programme. A tense relationship between NASA and the Smithsonian had existed since even before the recovery of Antarctic meteorites, with an early NASA curator (Duke 1976) suggesting that a centralized facility for the curation of all meteorites under the NASA model might be appropriate. During later years, the Smithsonian would be accused by a NASA curator of doing 'cardboard-box curation'. From its vantage point, the Museum viewed NASA as obstructionist in permanently releasing Antarctic meteorites to be accessioned by the Smithsonian into the USNM collection. Tension was heightened by the administrative structure of the ANSMET Programme, which created the Meteorite Working Group to oversee operations. This group included permanent representatives of the member agencies and rotating members from the academic community. In many cases, the greatest resistance to meteorite transfers came from the academic community, who viewed NASA as more responsive to their needs.

The resolution to this difference of opinion came in 1983, when the Smithsonian opened its Museum Support Center in Suitland, Maryland (Fig. 16). This state-of-the-art collections facility is centred on four pods (football-field-sized buildings approximately 50 feet high) connected by a corridor of offices and laboratories. Shortly after its opening, planning began on building what became essentially a duplicate of the dry nitrogen storage facility for Antarctic meteorites at Johnson Space Center in Houston and the new Museum storage facility opened in the fall of 1986. The first significant transfer (126 specimens) of Antarctic meteorites to the Smithsonian occurred in 1987. Even after its completion, the number of meteorites permanently transferred to the Smithsonian remained at a trickle for the next 5 years. Regular, annual transfers from Johnson Space Center to the Museum began in 1992 and the flow of meteorites increased tremendously in 1998. At that point, the Meteorite Processing Laboratory at Johnson Space Center was essentially full and the subsequent influx of newly-recovered meteorites necessitated the transfer of large numbers of specimens to the Smithsonian Institution. By the end of 2004, more than 11 300 individual specimens had been transferred to the Museum. When coupled with the chips and thin sections used for the initial classification, Antarctic meteorites now represent more than 80% of named meteorites in the Smithsonian collection and more than 70% of all specimens. These percentages alone demonstrate the spectacular impact of the

Fig. 16. Meteorite collection manager Linda Welzenbach working in the dry nitrogen storage cabinets at the Museum Support Center in Suitland, Maryland, in 2002. Meteorites are stored within stainless steel pans that are arranged within each of the cabinets. Photograph by Chip Clark.

Antarctic Meteorite Programme on the NMNH's meteorite collection.

The future

The meteorite collection continues as a focal point for the research and outreach efforts of the current staff and Antarctic meteorites dominate the landscape of the collection. Much as it was in early 1969, the current staff, augmented by a steady stream of NASA-funded postdoctoral fellows, is actively involved in research preparing for the return of extraterrestrial materials by spacecraft, although this time the targets are comets, asteroids and Mars. McCoy was the first USNM scientist to serve on a spacecraft team with his role on the Near-Earth Asteroid (NEA) Rendezvous mission to asteroid 433 Eros. MacPherson is deeply involved with planning for Mars sample returns. There is every reason to believe that meteorite collections will become increasingly important as the benchmark to which all new returned samples are compared.

Notes

[1]See Torrens (2004*a*). A recent retelling of the Macie–James Smithson story placing it in the social and scientific setting of the day is *The Stranger and the Statesman*, by Nina Burleigh (2003). Its treatment of Smithson's science is faulty.

[2]His father was Hugh Smithson (1715–1786), first Duke of Northumberland, and his mother Elizabeth Hungerford Keate Macie (1732–1800).

[3]Waterston (1965) and Torrens (2004*b*).

[4]A copy of Smithson's letter to Greville from the British Library, Greville Papers Add. 41100, numbers 82 is in the Smithsonian Institution Archives (SIA) RU7000, Box 1, folder 10.

[5]H.P. Ewing is completing the first comprehensive biography of Smithson, with anticipated publication by Bloomsbury, London, in the spring of 2007.

[6]A packing list dated 22 November 1796 covering specimens Thomson sent to Smithson in London survives in SIA RU 7000 box 2, f. 2. Item 7 is vitrolated tartar from the cone of Vesuvius as described in Smithson's paper. Heather Ewing has read much of William Thomson's correspondence and has authenticated the hand.

[7]A woodcut of the Chemical Laboratory *c.* 1856 is reproduced as fig. 32 in Field *et al.* (1993). Smithsonian Institution negative numbers 43804-E.

[8]The Ring *c.* 1863–1865 may be seen in Field *et al.* (1993, fig. 69). It is the centre of interest in fig. 117, *c.* 1871. Both photographs are from a private collection.

[9]Baird's letter of 3 December 1883 appointing Clarke as Honourary Curator, SIA RU7080, folder 2.

[10]Related Clarke–Shepard correspondence is in SIA RU7283 and in Smithsonian Institution accession records.

[11]Biographical material on Merrill may be found in the following: Farrington (1930), Schuchert (1930, 1931), and Lindgren (1935).

[12]See 'An historical account of the Department of Geology in the U.S. National Museum', G.P. Merrill (*c.* 1929) manuscript in the SIA, accession 98–012.

[13]G.K. Gilbert's letter of invitation of 15 October 1891, SIA RU7177, Box 2.

[14]G.K. Gilbert's letter of 8 November 1907 discussing possible meteorite formation of Meteor Crater, SIA RU7006, Box 41.

[15]S.H. Perry to Merrill, 21 May 1928, SIA RU7771, Box 20.

[16]S.H. Perry to Merrill, 10 May 1929, SIA RU7006, Box 41.

[17]G.P. Merrill to A. Wetmore, 14 August 1926, SIA RU7006, Box 41.

[18]William A. Foshag (1894–1956) joined the staff as a mineralogist in 1919, and carried out important work on meteorites in the late 1930s and early 1940s. Earl V. Shannon was a mineralogist–chemist.

[19]E. Henderson to H. Nininger, 12 March 1938, SIA, RU 268, Box 7.

[20]H. Nininger to E. Henderson, 13 July 1938, SIA, RU 268, Box 7.

[21]H. Nininger to A. Wetmore, 12 May 1939, SIA, RU 305.

[22]A. Wetmore to H. Nininger, 1 June 1939, SIA, Acc. 151638.

[23]For a listing of their papers see Mason & Clarke 1994.

[24]For more on the significance of Perry's findings, see Burke (1986) and forthcoming paper by Plotkin & Clarke 'Stuart H. Perry's Contributions to Smithsonian Meteoritics 1927–1957'.

[25]A listing of the meteorites that Perry donated to the Smithsonian can be gleaned from Perry (1955).

[26]H. Nininger to E. Henderson, 2 April 1958, SIA, RU 192, Box 658, Acc. 219370.

[27]H. Nininger to E. Henderson, 17 June 1958, SIA, RU268, Box 7.

[28]E. Henderson to L. Carmichael, 24 January 1961, SIA, RU 155, Box 13.

[29]E. Anders to H. Urey, 10 November 1961, SIA, RU 268, Box 1. For more on the jurisdictional dispute between the National Museum of Natural History and the Smithsonian Astrophysical Observatory see Plotkin (1997).

[30]E. Henderson to H. Suess, 16 June 1961 and E. Henderson to J. Arnold, 22 June 1961.

[31]G. A. Cooper to J. Bradley, 9 August 1961, SIA, Acc. 236677.

[32]For more on Henderson's and Mason's joint Australian field work, see Plotkin (1999).

[33]For a listing of the Smithsonian's meteorite collection as of 1973, see Mason (1975*b*).

[34]B. Mason, *Antarctic Meteorite Newsletter*, **66**, 3 (1983).

[35]Unsigned Introduction, *Antarctic Meteorite Newsletter*, **1**, no. 1, 1–3 (1978).

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References

BARRINGER, D.M. 1905. Coon Mountain and Its Crater. *Proceedings of the Academy of Natural Sciences of Philadelphia*, **57**, 861–886.

BUCHWALD, V. 1975. *Handbook of Iron Meteorites*, 3 vols. University of California Press, Berkeley, CA.

BUCHWALD, V.F. & CLARKE, R.S., JR. 1993. A mystery solved: the Port Orford meteorite is an Imilac specimen. *In:* CLARKE, R.S., JR (ed.) *The Port Orford, Oregon, Meteorite Mystery*. Smithsonian Contributions to the Earth Sciences, **31**, 25–43.

BURKE, J.G. 1986. *Cosmic Debris: Meteorites in History*. University of California Press, Berkeley, CA.

BURLEIGH, N. 2003. *The Stranger and the Statesman*. William Morrow–Harper Collins, New York.

CASSIDY, W.A. 2003. *Meteorites, Ice, and Antarctica*. Cambridge University Press, Cambridge.

CLARKE, F.W. 1888. *The Constants of Nature. Part I. Specific Gravity for Solids and Liquids. New edition, revised and enlarged*. Smithsonian Miscellaneous Collections, **659**.

CLARKE, F.W. 1889. *The Meteorite Collection of the U.S. National Museum: A Catalogue of Meteorites Represented November 1, 1886*. Report of the Smithsonian Institution, 1885–86, part 2, 255–265. (With addenda to 20 October 1888.)

CLARKE, F.W. 1892. The relative abundance of the chemical elements. *Bulletin of the Philosophical Society of Washington*, **11**, 131–142.

CLARKE, F.W. 1959. *The Data of Geochemistry*, 5th edn. *U.S Geological Survey Bulletin*, **770**, 841. First edn, published as *Bulletin*, **330** (1908).

CLARKE, R.S., JR. 1986. Antarctic iron meteorites: an unexpectedly high proportion of falls of unusual interest. *In:* ANNEXSTAD, J.O., SCHULTZ, L. & WÄNKE, H., (eds) *International Workshop on Antarctic Meteorites*. Lunar Planetary Institute Technical Report, 86–01, 28–29.

CLARKE, R.S., JR & GOLDSTEIN, J.I. 1978. *Schreibersite Growth and Its Influence on the Metallography of Coarse-structured Iron Meteorites*. Smithsonian Contributions to the Earth Sciences, **21**, 1–80.

CLARKE, R.S., JR, JAROSEWICH, E., MASON, B., NELEN, J., Gómez, M. & HYDE J.R. 1971*a*. *The Allende, Mexico, Meteorite Shower*. Smithsonian Contributions to the Earth Sciences, **5**.

CLARKE, R.S., JR, JAROSEWICH, E. & NELEN, J. 1971*b*. The Lost City, Oklahoma, meteorite: An introduction to its laboratory investigation and comparisons with Pribram and Ucera. *Journal of Geophysical Resesearch*, **76**, 4135–4143.

CRONIN, J.R., PIZZARELLO, S. & CRUIKSHANK, D.P. 1989. Organic matter in carbonaceous chondrites, planetary satellites, asteroids and comets. *In*: KERRIDGE, J.F. & MATTHEWS, M.S. (eds) *Meteorites and the Early Solar System*. University of Arionza Press, Tucson, AZ, 819–857.

DAVIS, W.M. 1926. Biographical memoir of Grove Karl Gilbert 1843–1918. *Biographical Memoirs of the National Academy of Sciences*, **21**, 1–303.

DUKE, M. 1976. Application of lunar curatorial experience to meteoritic samples. *Meteoritics*, **11**, 277–278.

FARRINGTON, O.C. 1930. Tribute to George Perkins Merrill. *Bulletin of the Geological Society of America*, **41**, 27–29.

FIELD, C.R., STAMM, R.E. & EWING, H.P 1993. *The Castle: An Illustrated History of the Smithsonian Building*. Smithsonian Institution Press, Washington, DC.

GEIKIE, SIR A. 1907. *A Journey Through England and Scotland to the Hebrides in 1784* by B. Faujas de St. Fond. Revised edition of the English translation, edited, with notes and a memorial to the Author, Volumes I & II. Hugh Hopkins, Glasgow.

GILBERT, G.K. 1896. The origin of hypotheses, illustrated by the discussion of a topographic problem. *Science*, **3**, 1–13.

GOODE, G.B. 1897. *The Smithsonian Institution 1846–1896: The History of its First Half Century*. The Smithsonian Institution, Washington, DC.

HAMILTON, W. 1795. An account of the late eruption of Mount Vesuvius. *Philosophical Transactions*, **85**, 73–116.

HENDERSON, E.P. 1949. *American Meteorites and the National Collection*. Smithsonian Institution Report for 1948. The Smithsonian Institution, Washington, DC, 257–268.

HENDERSON, E. & PERRY, S.H. 1958. Studies of seven siderites. *Proceedings of the United States National Museum*, **107**, 339–403.

HENSON, P.M. 2004. A national science and a national museum. *Proceedings of the California of Sciences*, **55**, (Suppl. 1), 34–57.

HENRY, J. 1854. *Report of the Secretary*. Ninth Annual Report of the Board of Regents of the Smithsonian Institution for 1853. Smithsonian Institution, Washington.

HOYT, W.G. 1987. *Coon Mountain Controversies: Meteor Crater and the Development of Impact Theory*. University of Arizona Press, Tucson, AZ.

JAROSEWICH, E., CLARKE, R.S., JR & BARROWS, J.N. (eds). 1987. *The Allende Meteorite Reference Sample*. Smithsonian Contributions to the Earth Sciences, **27**.

JOHNSON, W.R. 1844. A memoir on the scientific character and researches of James Smithson, Esq., F.R.S. Reprinted in Rhees (1879), *The Scientific Writing of James Smithson*. Smithsonian Miscellaneous Collections, 123–141.

KOJIMA, H. 2006. The history of Japanese Antarctic meteorites. *In*: MCCALL, G.J.H., BOWDEN, A.J. & HOWARTH, R.J. (eds) *A History of Meteoritics and Key Meteorite Collections: Fireballs, Falls and Finds*. Geological Society, London, Special Publications, **256**, 291–303.

LINDGREN, W. 1935. Biographical memoir of George Perkins Merrill, 1854–1929. *Biographical Memoirs of the National Academy of Sciences*, **27**, 33–53.

MARVIN, U.B. 1996. Ernst Florens Friedrich Chladni (1756–1827) and the origins of modern meteorite research. *Meteoritics and Planetary Science*, **31**, 545–588.

MARVIN, U.B. 2002. Oral histories in meteoritics and planetary science: V. Brian Mason. *Meteoritics and Planetary Science*, **37**, B35–B45.

MARVIN, U.B. 2006. Meteorites in history: an overview from the Renaissance to the 20th centuries. *In*: MCCALL, G.J.H., BOWDEN, A.J. & HOWARTH, R.J. (eds) *A History of Meteoritics and Key Meteorite Collections: Fireballs, Falls and Finds*. Geological Society, London, Special Publications, **256**, 15–71.

MASON, B. 1963 Olivine composition in chondrites. *Geochimica et Cosmochimica Acta*, **27**, 1011–1023.

MASON, B. 1975*a*. Mineral sciences in the Smithsonian Institution. *In*: SWITZER, G.S. (ed.) *Mineral Sciences Investigations 1972–1973*. Smithsonian Contributions to the Earth Sciences, **14**, 1–10.

MASON, B. 1975*b*. *List of Meteorites in the National Museum of Natural History, Smithsonian Institution*. Smithsonian Contributions to the Earth Sciences, **14**, 71–83.

MASON, B. & CLARKE, R.S., JR. 1994. Memorial of Edward P. Henderson. *American Mineralogist*, **79**, 579–580.

MASON, B. & MELSON, W.G. 1970. *The Lunar Rocks*. Wiley-International, New York.

MCCALL, G.J.H. 2006*a*. Chondrules and calcium–aluminium-rich inclusions (CAIs). *In*: MCCALL, G.J.H., BOWDEN, A.J. & HOWARTH, R.J. (eds) *A History of Meteoritics and Key Meteorite Collections: Fireballs, Falls and Finds*. Geological Society, London, Special Publications, **256**, 345–361.

MCCALL, G.J.H. 2006*b*. Meteorite cratering: Hooke, Gilbert, Barringer and beyond. *In*: MCCALL, G.J.H., BOWDEN, A.J. & HOWARTH, R.J. (eds) *A History of Meteoritics and Key Meteorite Collections: Fireballs, Falls and Finds*. Geological Society, London, Special Publications, **256**, 443–469.

MERRILL, G.P. 1908. *The Meteor Crater of Canyon Diablo, Arizona; Its History, Origin, and Associated Meteoric Irons*. Smithsonian Miscellaneous Collections, **50**, 461–498.

MERRILL, G.P. 1916. *Handbook and Descriptive Catalogue of the Meteorite Collections in the United States National Museum*. US National Museum Bulletin, **94**.

MERRILL, G.P. 1929. *Minerals from Earth and Sky. Part I. The Story of Meteorites*. Smithsonian Institution Science Series, **3**.

MERRILL, G.P. 1930. *Composition and Structure of Meteorites*. US National Museum Bulletin, **149**.

MILLER, A.M. 1923. Meteorites. *The Scientific Monthly*, **17**, (November), 435–448.

NORTON, O.R. 1994. *Rocks from Space*. Mountain Press, Missoula, MT.

PERRY, S.H. 1944. *The Metallography of Meteoric Iron*. US National Museum Bulletin, **184**.

PERRY, S.H. 1955. *Meteorite Collection of Stuart H. Perry, Adrian, Michigan*. Privately printed, 1–23.

PLOTKIN, H. 1993. John Evans and the Port Orford meteorite hoax. *In*: CLARKE, R.S., JR. (ed.) *The Port Orford, Oregon, Meteorite Mystery*. Smithsonian Contributions to the Earth Sciences, **31**, 1–24.

PLOTKIN, H. 1997. The Henderson network vs. the Prairie network: The dispute between the Smithsonian's National Museum and the Smithsonian Astrophysical Observatory over the acquisition and control of meteorites, 1960–1970. *Journal of the Royal Astronomical Society of Canada*, **91**, 32–38.

PLOTKIN, H. 1999. The Australian Meteorite Expedition of 1963: Edward P. Henderson's unpublished recollections. Part I. *Meteorite*, **5**, (1), 16–20; Part II. *Meteorite*, **5**, (2), 24–27.

RHEES, W.J. 1879. *The Scientific Writings of James Smithson*. Smithsonian Miscellaneous Collections, **327**, 1–159.

RHEES, W.J. 1880. *James Smithson and his Bequest*. Smithsonian Miscellaneous Collections, **330**, 1–68.

ROE, A. 1975. The C.U. Shepard mineral collection and the two Drs. Shepard. *Mineralogical Record*, **6**, 253–257.

SCHMITT, D. 2002. The law of ownership and control of meteorites. *Meteoritics and Planetary Science*, **37**, (Suppl.), B5–B11.

SCHUCHERT, C. 1930. *George Perkins Merrill (1854–1929)*. Report of the Smithsonian Institution for 1930, Part 1. The Smithsonian Institution, Washington, DC, 617–634.

SCHUCHERT, C. 1931. Memorial of George Perkins Merrill. *Bulletin of the Geological Society of America*, **42**, 95–122.

SILLIMAN, B. 1886. Memoir of John Lawrence Smith. *National Academy of Sciences Biographical Memoirs*, **II**, 217–248.

SMITH, J.L. 1855. Memoir on meteorites – a description of five new meteoric irons, with some theoretical considerations on the origin of meteorites based on their physical and chemical character. *American Journal of Science*, **19**, 153–163, 322–342.

SMITH, J.L. 1856. *Lecture on Meteoric Stones*. Smithsonian Institution Annual Report for 1855, 151–174. Essentially a reprint of the *American Journal of Science*, **19**, 153 and **19**, 322 (1855) papers.

SMITHSON, J. 1803. A chemical analysis of calamines. *Philosophical Transactions of the Royal Society (London)*, **93**, 12–28.

SMITHSON, J. 1813. On a saline substance from Mount Vesuvius. *Philosophical Transactions of the Royal Society (London)*, **103**, 256–262.

TASSIN, W. 1902. *Descriptive Catalogue of the Meteorite Collection in the United States National Museum to January 1, 1902*. Report of the United States National Museum for 1900, 671–698, Smithsonian Institution, Washington.

TILGHMAN, B.C. 1905. Coon Mountain and Its Crater. *Proceeding of the Academy of Natural Sciences of Philadelphia*, **57**, 861–886.

THOMSON, G. (WM.) 1804. Essai sur le fer malléable trouvé en Siberie par le Professeur Pallas. *Bibliothéque Britannique*, **27**, 135–154, 209–229.

TORRENS, H.S. 2004*a*. Smithson [*formerly* Macie], James Lewis (1764–1829). *In*: *Dictionary of National Biography*, Volume 51. Oxford University Press, Oxford, 400–403.

TORRENS, H.S. 2004*b*. Thomson, William (*bap*. 1760–1806). *In*: *Dictionary of National Biography*, Volume 54. Oxford University Press, Oxford, 562–563.

WATERSTON, C.D. 1965. William Thomson (1761–1806) a forgotten benefactor. *University of Edinburgh Journal*, **22**, autumn, 122–134.

WILLEY, R.R. 1987. *The Tuscon Meteorites*. Smithsonian Institution Press, Washington, DC.