History of the American Museum of Natural History meteorite collection

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Abstract:

The core meteorite collection of the American Museum of Natural History, New York, including the massive Cape York and Willamette irons, dates from the three decades ending in 1905. Acquisition of new meteorites was steady into the 1970s, and accelerated in the latter 20th century. Institutional and philanthropic support, coupled with the focus, energy and vision of a succession of curators, have been central to building the collection, exhibiting meteorites, educating the public, and participating at the cutting edge of meteoritical science. Efforts to describe and classify, characteristic of the pre-war period, evolved into detailed chemical investigations. Recent science seeks to find underlying processes unifying disparate meteorite groups in a coherent story of the early solar system and planet formation.

In the early years, meteorites usually formed small subsets of mineral collections. The great museums grew by acquisition of such collections. Meteorite science became important in its own right in concert with interest in planetary science and particularly following the landing of people on the moon. Personnel and science at the AMNH reflect these changes. This chapter begins with the historical development of the collection itself, particularly the stories of the big irons, and the custody of the collection by curators and departments within the Museum. Our next concern is the public face of the collections: their display. Finally, the rise of collection-based meteorite science is explored, with concomitant rise in collaborative research on the global aggregate collection that is our human patrimony. As with palaeontology, anthropology and zoology, there is a century-long shift from *accumulation* to *understanding*; from collections that speak for themselves, to collections invested with meaning by investigation of the logical tissues that bind their parts; from *facts* to, we hope, *knowledge*. This is a snapshot of how we got here, and an anticipation of great progress in the coming century, in which meteorites will become a subset of the extraterrestrial samples in our research arsenal.

The Beginning

The meteorite collection of the American Museum of Natural History dates to the very earliest years of the Museum. The AMNH was chartered by the state of New York in 1869, under the leadership of Albert Smith Bickmore (1839-1914). Bickmore had attended Dartmouth, then Harvard from 1861 to 1865, where he was strongly influenced by Louis Agassiz at the Museum of Comparative Zoology. After travel to the far east, and a visit to Sir Richard Owen, founder and first Superintendent of the British Museum (Natural History), London, Bickmore returned to New York ready to make real Agassiz's vision of an American natural history museum. Bickmore was a charismatic proselytiser of natural science, who quickly sparked similar enthusiasm among public-spirited citizens and philanthropists of the era. Finding favour with Theodore Roosevelt, Sr., and several friends, the new Museum was housed in the old Arsenal in Central Park, now the administrative headquarters of the Parks Department of New York City. The formal relationship (c. 1869) between the City and the Museum, through its Trustees, was "a most fortunate circumstance in the educational history of the City of New York... a new idea in municipal government" (Osborn 1911, p.12), and formed the model for the Metropolitan Museum of Art, New York Botanical Garden , and other great institutions. The natural history collection was displayed *en masse*, without the topical separation we are today accustomed to seeing. Collections quickly outgrew the Arsenal, and the Museum petitioned the city for land. Construction of a grand, never fully-realized design by the architect Calvert Vaux began at Manhattan Square, on the west side of the park. The cornerstone for "the new fire-proof building provided for our Collections by the liberality of the People of this City" was laid by President Ulysses S. Grant on June 2, 1874 (AMNH 1874). The first building was completed in 1878, with minerals, meteorites and fossils on the fourth floor (Fig. 1). The next five buildings, facing 77th Street, were completed by 1900 (Fig. 2; AMNH-www 2005; Preston 1986, plate 3). In the new building, the mineralogical collections, including meteorites, were displayed in a separate hall. In those early years, meteorites were curated by Robert Parr Whitfield (1828-1916), an invertebrate palaeontologist. Whitfield was the first named Curator in the Museum (AMNH 1878), and first curator of the variously named departments that until 1900 included mineralogy. Whitfield described several meteorites in the scientific literature (e.g., Whitfield 1887, 1889).

< Fig. 1: First building plan of AMNH >

< Fig. 2: South Facade of AMNH (either 1900 or 1907 photo) >

In 1871, the Searsmont ordinary chondrite fell in Waldo County, Maine. The first recorded AMNH meteorite specimen is catalogued as "Fragments of Meteorite from Searsmont, Me.", donated Feb. 15, 1872 by Mr. G. M. Brainerd of Maine (AMNH 1872). All donations in those years were noted in the Annual Reports, however this Searsmont specimen is not listed in the Hovey (1896) catalogue, and is not in today's collection. The meteorite collection grew by eight specimens in 1875, with acquisition for $5000 (Peters & Pearson 1990) of the mineral collection of Stratford C. Harvey (S.C.H.) Bailey (1822-1910), a prominent New York lawyer (W. Wilson, pers. comm., July 2005). In the financially difficult 1870s, the manufacturer and mineral collector Clarence S. Bement (1843-1923) offered his mineral collection to the Museum (1877), but there are no records the offer was seriously considered. Luckily, Bement's business survived the times, and his collection remained intact. About 1882, Bement 'high-graded' the mineral collection belonging to Norman Spang (1843-1922) of Pennsylvania, then considered one of the finest private collections. That is, Bement bought the right to take specimens from localities he did not possess, and particularly fine duplicates of ones he did. In 1885, the Museum obtained some very fine specimens of the Estherville, Iowa meteorite fall of that year. The remainder of the Spang mineral collection was purchased by the Museum in 1891 for $8000, and contained 21 meteorites. This early, modest growth of the collection is documented in the first meteorite catalogue, by Edmond Otis Hovey (1896), for a total of 55 specimens representing 26 individual falls and finds.

In 1900, the Bement collection of minerals was purchased, and presented to the Museum, by the philanthropist and trustee John Pierpont Morgan (1837-1913). This immediately catapulted the Museum into the forefront of meteorite and mineral collections. The Bement mineral collection is considered the finest ever assembled by an individual (Peters & Pearson 1990). It also included 580 meteorite specimens, representing nearly 500 individual falls and finds (Reeds 1937). Among them was the 41g. specimen of Searsmont present in today's collection. Bement's meteorites are the nucleus: the 'critical mass' that would stimulate the interest of Museum curators in building a world-class collection.

<< Fig. 3: Hammond meteorite etched slab. >>>

Clarence Sweet Bement (1843-1923) was born in Mishewaka, Indiana, April 11, 1843. He is reported to have started collecting meteorites in the early 1880s, with varying interest over the years (Peters & Pearson 1990, p. 55), however there is solid evidence of his earlier efforts (Fig. 3). Many of his meteorite specimens were purchased from the firm Ward & Howell, a predecessor to Ward's Natural Science Establishment. In letters to George F. Kunz (about whom more later), Bement wrote: "The craze on this subject has assumed such an intensity that I feel very much like abandoning the field, for I don't see so much value in specimens so nearly alike and lacking crystallization, which is the main interest to me in most minerals." (Bement 1885a); and later lamented: "W&H are stiff in pricing meteorites. It is very possible I will not buy any more" (Bement 1885b). But despite prices he considered excessive, Bement kept with it, and in a letter to Prof. Wolff at Harvard he wrote (Bement 1896):

> "The ideas of private collections vary, but my desire is to procure specimens large enough to show the physical characters, as well as to satisfy the needs of a museum in the event of a sale of the collection... which I hope may be deferred at least so long as I live ... I have over 350 falls which I shall hope to increase to 400 before too long."

Bement prized meteorites highly, and his 1897 catalogue, which he compiled himself, lists 413 individual falls and finds (Bement 1897). As his collection grew, it became increasingly difficult to find material anywhere that was worth adding. Acquisition or high-grading of world-class collections became a necessity.

Experts such as Henry Augustus Ward (1834-1906) and George Frederick Kunz (1856-1932) could travel the world as buyers, knowing what Bement and others already possessed, and assured that they would be interested in new localities and spectacular specimens. Ward and Kunz would today be considered dealers. In their travels they amassed collections which they sold to wealthy patrons, then proceeded to build new collections. Eventually, many of these nineteenth-century collections became the foundations for American museums. Kunz made twelve collections of gems alone; the finest is at the AMNH, another, the Chicago Exposition Collection, is at the Field Museum (Conklin 1998). The Smithsonian, Field, and American Museums all began with world-class mineral collections, usually including meteorites and fossils. Other significant collections of this era went to Yale, Harvard, and Amherst (Ward 1904a; Canfield 1923).

A new Department of Mineralogy was created in 1900, with Louis Pope Gratacap, A.M., Ph.D. (1851-1917) as its first curator, especially to house the Bement collection (AMNH 1900). Gratacap had cared for shells, minerals and meteorites as Assistant Curator of the Geological Department, from 1880 to 1900, under Robert Parr Whitfield. Gratacap commuted from the wilds of Staten Island, but his real home was the Museum with which he was associated from October 1876, until his death as Curator of the Department of Mineralogy and Conchology, on December 19, 1917. He was a prolific and popular writer on minerals, molluscs, and many other subjects (Gratacap 1905, 1909, 1912). Perhaps his most interesting work is the 1903 fiction, *The Certainty of a Future Life in Mars*, which included a reprinting of Giovanni Schiaparelli's *The Planet Mars*, upon whose canal-laced landscape was grafted a wonderfully imagined world of souls (see also Consolmagno, this volume). A random sample of Gratacap's gift for prose: "Meteorite ... designations sometimes of necessity assume a curious character, as the Vaca Muerta meteorite, or 'dead cow', so named in the desert of Atacama, Chili (sic), from its proximity to the corpse of that quadruped, the only, or at least a striking, physical feature in an otherwise featureless waste. Such a name remains after its origin has disappeared" (Gratacap 1906, p. 23).

< Fig. 4: Morris Ketchum Jesup >

The Great Irons: Cape York and Willamette

The Arctic explorer Robert Edwin Peary (1856-1920; then a naval lieutenant) came to the attention of the Museum's third president Morris Ketchum Jesup (1830-1908) in the early 1890s. Jesup (Fig. 4) served from 1881 to 1908, and formed the Peary Arctic Club to finance and publicise Lieutenant, later Commander, Peary's expeditions. Jesup facilitated Peary's leave from the Navy by writing to President McKinley (Preston 1986). In 1894, in the Arctic spring, Peary decided to locate the fabled "iron mountain" (*sowallik*, Ross 1819; later "*Saviksue*" of Peary 1898; cf. Buchwald 1975, p. 412) of Greenland. In 1818, the English explorer Sir John Ross (1777-1856) had encountered native people using knives, scrapers and spearheads (Ross 1819) made of what was later determined to be nickel-rich meteoritic iron. Subsequent expeditions had been unable to locate this iron mountain, and its existence was in doubt following the discovery of rare native iron at Disko Island, Greenland. Since 1850 the Eskimos had been trading for iron and guns, and had almost forgotten about the meteorites (Buchwald 1975). They were friendly with Lieutenant Peary, who lived with them on and off for 19 years. In spring of 1894, native guide Tallakoteah led Peary and expedition member Hugh Green, with a sled and ten dogs, through very severe conditions to the shore of Melville Bay. Peary reports (1898; Preston 1986) that Tallakoteah stopped on a large, level snowfield, cut down through the snow to expose the iron mass called "the Woman", and pointed out the locations of "the Dog" and "the Tent". These three iron masses are all fragments of the same meteorite fall, now known as Cape York. According to local legend reported *only* by Peary (1898 p. 559, 611; Buchwald 1975, p. 420), the evil spirit Tornarsuk had hurled a sewing woman, her dog, and their tent from the sky where they lived, and they landed on earth as lumps of iron. However, the distributions of these meteorites are not consistent with their fall being as recent as the < 1000 year human occupation of the area (Buchwald 1975), and Tallakoteah would surely have already known from his close association, that their guests thought that these iron masses fell from the sky.

Drifting ice prevented Peary from recovering the meteorites, and he returned to Melville Bay in 1895 with the steamship *Kite*. He brought with him the Quaternary geologist and geographer Prof. Rollin D. Salisbury (1858-1922) of The University of Chicago, to authenticate the find. The Woman (2727 kg, or 3 tons; AMNH #868) and The Dog (407 kg; AMNH #869) were located first. The Woman was surrounded by about 10,000 basalt cobbles transported from many miles away and used to hammer pieces of metal (including the 'head', Peary 1898, p. 146; Buchwald 1975, p. 412) off the meteorite. The Dog may, in fact, once have been part of the Woman (Buchwald 1975). These two specimens are smoothed out, and their microstructure was later found to be deformed to 3-5mm depth. The two were rolled and dragged to shore, and brought aboard with some difficulty. Peary reports that many native people gathered to watch this operation, perhaps expecting an entertaining disaster (Peary 1898). The Woman and Dog were brought to New York that year. The much larger Tent remained in its remote location on an island about 6 miles offshore. The Tent was found with few hammer-stones nearby, and shows little evidence of assault. In 1896, Peary returned with a larger ship, the *Hope*, hydraulic jacks, chains, ropes, railroad rails, and heavy timbers. The team dug around the meteorite, anchored the jacks beneath it, and laboriously rolled it to shore. In his wonderfully descriptive, illustrated account *Northward Over the Great Ice*, Peary wrote (1898, p. 569):

> The first thing to be done was to tear the heavenly visitor from its frozen bed of centuries, and as it rose slowly inch by inch under the resistless life of the hydraulic jacks, gradually displaying its ponderous sides, it grew upon us as Niagara grows upon the observer, and there was not one of us unimpressed by the enormousness of this lump of metal.

Perhaps when humans someday mine asteroids, they will again report on extraterrestrial metal's "utter contempt and disregard of all attempts to guide or control it when once in motion; and the remorseless way in which it destroyed everything opposed to it" (Peary 1898, p. 573). The Tent crushed the rocks onto which it rolled, and wore out the three hydraulic jacks. Finally, leaving it on a natural rock pier, Peary and crew fled the encroaching pack ice.

In 1897, Peary returned with *Hope*. The crew brought the ship very close to the shore, and placed steel rails, greased with tallow, across the water. The Tent was placed on a massive timber 'car', which moved across the rails onto the ship's deck (Fig. 5). The Tent was christened 'Ahnighito' (a string of nonsense syllables) by Peary's 4-year old daughter upon its arrival at the *Hope* (Peary 1898, p. 584). Peary wrote: "Never have I had the terrific majesty of the force of gravity and the meaning of the words 'momentum' and 'inertia' so powerfully brought home to me as in handling this mountain of iron" (1898, p. 570). President Jesup sent samples to the mineralogists Prof. Sir Lazarus Fletcher (1854-1921; British Museum), Ernst H. O. K. Weinschenk (1865-1921; Munich, Bavaria), and Prof. Maria Aristides Brezina (1848-1909; Vienna) for positive identification: Cape York was verifiably meteoritic iron.

< Fig 5. Moving Tent across rails onto ship's deck >

Ahnighito was brought to the Brooklyn Navy Yard, where it rested until 1904, when this most massive of the Cape York iron meteorite fragments came to the Museum. Crowds gathered to watch a barge bring it up the East River, and unload at the east 50th Street Pier, where a huge cart pulled by 28 horses brought Ahnighito to the Museum.

The three Cape York specimens were immediately displayed in Memorial Hall, inside the main 77th Street entrance (Fig. 2; Hovey 1907). Ahnighito (AMNH #867) is the largest and most massive meteorite on display in any museum or "in captivity", at 3.3m long, 2m high, and 1.6m thick, and 30,945 kg (68,080 lbs., or 34 tons avoirdupois), although this was not determined until 1958. The three Cape York specimens were formally purchased in 1909 for $40,000, through the generosity of Mrs. Morris K. Jesup. In 1914, another piece of Cape York, the Akpohon fragment (1559.1g, Reeds 1937), was discovered near an ancient settlement on Ellesmere Island (Buchwald 1975, p. 411, 425). Akpohon (AMNH #289) was accessioned in 1917. Five other specimens of Cape York have been found since. The largest, Agpalilik (20,140 kg), was recovered in 1963 and is in the Royal Museum at Copenhagen, Denmark (Buchwald 1975). As Peary states, a "combination of values renders these Cape-York 'Saviksue' peerless and unique among all the meteorites of the world" (1898, p. 618).

Two meteorites that remain *in situ* elsewhere in the world are larger than Ahnighito: the ~55,000 kg ataxite found at Hoba farm, South West Africa (now Namibia) in 1920; and the largest fragment of the Campo del Cielo meteorite, in the Argentina strewn field (Cassidy *et al.* 1965). Two pieces (9.7 and 6.6 g) of Hoba came to the AMNH (#2628) in 1930. The Bement collection included a 115.8 g piece of Campo del Cielo (AMNH #144). Hoba was declared a national monument in 1955, and has been partially excavated and enclosed (Buchwald 1975, pp. 647-650; Bevan & DeLaeter 2002, p. 35).

Campo del Cielo was first collected by Spanish explorers in 1576. The Argentine natives knew of the iron, which they regarded as having fallen from heaven. This lore is plausible, given that ^{14}C ages from contemporary charcoals indicate the fall was less than 6000 years ago (Buchwald 1975, pp. 373-379). Cassidy has made an extensive study of Campo del Cielo, and he used observed volume to estimate a mass of 20,500 kg for the largest piece (in his crater 10), assuming it was flat underneath (Cassidy 1971). About ten years later, Professor Argentino Romaña excavated it, named it the 'Chaco' fragment, and brought it to a cotton-exporter's truck scale, yielding 33,400 kg (Cassidy & Renard 1996). Ten years after that, collector Robert Haag again lifted the meteorite, although he was not successful in removing the mass from Argentina (Norton 1998). The scale on his crane registered 36,000 kg (W. Cassidy, pers. comm. Aug. 2003), and the meteorite remains in its crater.

The 15.5 ton (14,110 kg) Willamette (IIIA) iron meteorite (AMNH #203) was excavated in 1902 from a wooded ridge three miles northwest of Oregon City in Clackamas Co., Oregon, by Ellis Hughes (1859-1942), a former Welsh miner (Reeds 1937). It remains the largest meteorite ever found in the United States, and was at that time the third largest known meteorite. Following legal wrangling (Buchwald 1975; Preston 1986), ownership of Willamette was won by the Oregon Iron and Steel Company, upon whose land it had rested in human memory. The meteorite made a sensational appearance at the Mining Building of the Lewis and Clark Exposition in Portland in 1905. Through the generosity of Mrs. William E. Dodge, it was purchased for the Museum for $20,600 and put on display June 7, 1906. At that time, this was the highest price ever paid for any single specimen in the Museum's entire collections (Preston 1986). Aside from its size, the striking features of Willamette are its well-developed nose-cone shape and its deeply pitted top surface (Fig. 6). The scaled and rusty apex or nose-cone was about one metre below ground, with the opposite side (3 x 2 m) nearly parallel to ground (Ward 1904b). Investigators of the find site in 1948 reported nickel enrichment of the soil to a depth of several feet (Buchwald 1975, p. 1315). The upper, flat surface contains interpenetrating pits up to ~50cm deep, nearly perpendicular to the surface. Pedestals between the pits were broken off in the distant past. The pits represent removal of an estimated six tons of material (Buchwald 1975, p. 1318), by weathering of the exposed surface of the meteorite in the wet Oregon climate, as aerated rainwater collected with dissolved sulphur from numerous rod-shaped troilite (FeS) inclusions, producing sulphuric acid (Buchwald 1975). Similar sulphide inclusions are present in all irons, but in this case they conspired with rain, gravity and time to produce a unique texture.

In recent years, the Confederated Tribes of Grand Ronde filed a claim under the Native American Graves Protection and Repatriation Act, demanding repatriation of the meteorite. The AMNH and the Confederated Tribes of the Grande Ronde Community signed an agreement on June 22, 2000 that enables the Tribe to re-establish its relationship with the meteorite through an annual ceremonial visit. As part of the agreement, the tribe agreed to drop its claim for repatriation of the meteorite and not to contest the Museum's ownership of it. In addition to the annual Tribal delegation visits, the Museum has also established an internship for Native American young people, with Grand Ronde tribal members as its first participants.

Cape York and Willamette are both medium octahedrites of group III. Each has experienced different degrees of shock and reheating in space. Numerous scientific studies of both have appeared in the literature (Buchwald 1975). The story of Cape York has been told in many places (Buchwald 1975; Reeds 1937; Preston 1986), but most comprehensively by Peary himself (1898), whose account included numerous amazing photographs. Parts of the Willamette story can be found in Kunz (1904), Hovey (1906), and Preston (1986). The most complete account is that of Ward (1904b, with nine photographs). Buchwald (1975, p.1314) reviews the five rare cases of legal disputes involving meteorites (3 U.S., 2 French).

<< Fig. 6: Willamette meteorite in the Rose Center at AMNH (AMNH web) >>>

Building the Collection

The Cape York and Willamette meteorites are arguably the most spectacular meteorites on display anywhere in the world, and have probably been viewed by more people than any other meteorites. As objects of wonder, they introduce visitors to the majesty of the cosmos in a visceral way. Iron meteorites, however, are now known to represent less than 5% of all meteorites that fall to earth (Zolensky 1998). Scientific researches on meteorites, as witnesses to the birth of the solar system, and as pieces of other planetary bodies, depend upon the continued growth of museum collections. Morris Jesup, a man with little formal education, had impressed upon the museum the importance of collections as the very *facts* of natural history. To nineteenth-century natural scientists, collections revealed the relationships of nature. They continue to do so, and remain a resource to be held in trust long into the future. In this spirit, the meteorite collection of George Kunz was purchased for the Museum by J. P. Morgan in 1905.

George Frederick Kunz, A.M., Ph.D., D. Sc. (1856-1932) was the most famous mineral and gem expert of his own time, and perhaps of any since. Kunz worked at Tiffany and Co., jewellers, for over 50 years and was an honorary curator of gems at the Museum after 1902. He founded the still thriving New York Mineralogical Club in 1886. Kunz had an active interest in meteorites and from 1885 to 1893 described numerous meteorites from the United States (Kunz 1885, 1886, 1887, 1890; Kunz & Weinschenk 1892; Kunz & Huntington 1893). He acted as agent for C.S. Bement and other collectors, often purchasing and exchanging meteorites. Kunz assembled the 1893 "Columbia Exposition Collection" of minerals, gems, also including some meteorites, which he then sold to the Field Columbian Museum of Natural History in Chicago upon its founding in 1894. Kunz was a prolific scholar and writer on gems and minerals. His interest in all things mineral began early (Conklin 1998, p. 111):

> At the age of fourteen I started sending specimens abroad for exchange, and had already begun that unending stream of correspondence on mineralogy which now inundates the vaults of several museums, the cellars and several of the rooms of my home, my private offices, and heaven knows what outlying territories. It all seems to me very interesting and important, though I suppose its custodians would gladly see it heaped in a pyre on the Mall of Central Park, its flames licking the sky.

That amazing collection of letters resides in the AMNH archives. Today, Kunz might be thought more a *dealer* than a *collector*, although his appreciation of posterity must be acknowledged in the generous terms given to the Museums he allowed to buy his material. He had a particular interest in meteorites, and the 1905 accession of his collection added 186 new falls and finds to the AMNH collection.

A meteorite collection among the top four in the world required continued acquisition. In 1906, the newly-found main mass of Selma, Alabama (H4, 141 kg) was purchased, and a third of the Russel Gulch iron meteorite found in Colorado in 1863 was presented to the museum. Selma was at that time the largest stony meteorite ever found. Samples of Ness County, Modoc, Brenham, Tamarugal, a section of Gibeon, and the entire Knowles iron (found in Oklahoma in 1903, 161 kg.) were obtained in succeeding years.

Mineralogy and Conchology had become a separate Department in 1901, and the meteorite catalogues, including the Bement specimens, were transferred from Mineralogy back to Geology in 1910, when Edmund Otis Hovey, Ph.D. (1862-1924) became Curator, having been Assistant Curator (1894-1900) and Associate Curator (1901-1909). Hovey appears to be the early curator with greatest interest in meteorites, although he also did pioneering fieldwork in volcanology (Hovey 1902). He described many meteorites (e.g., Willamette 1906, Guffey 1909, Johnstown 1925), and continued to add meteorites to the collection until his death on Sept. 24, 1924. In 1910 Hovey separated the folio catalogue for meteorites from the mineral catalogue.

The first major mineral collection of the AMNH, between 5000 and 7000 specimens, had been acquired from S. C. H. Bailey in 1875 for $5000, and displayed in the Old Arsenal Building (Peters & Pearson 1988). A second Bailey collection, with 3915 minerals and 293 meteorites, was acquired in 1912 from his niece, through the generosity of Mr. J. Pierpont Morgan, Jr. (1867-1943). Also in 1912, many other significant specimens were obtained, including many hundreds of pieces of Holbrook, the main mass of Tomhannock Creek (NY, 1.6 kg), and an entire piece of Cruz del Aire (15 kg), which is on display in the present Meteorite Hall. The next year, 32 specimens were added, 24 of individual meteorites new to the collection. Exchanges for material from the Bailey collection were instrumental in these additions. The geologist Chester A. Reeds, Ph.D. (1882-1968) was hired in Oct. 1912 as Assistant Curator, initially to sort out the labels and specimens of the Bailey minerals that were scrambled in transit. Dr. Reeds became acting curator in the Dept. of Geology, in 1916-17, then Associate Curator (1917-1927), and Curator 1927-1938. Hovey and Reeds added a large number of specimens during their tenures (Fig. 7), each detailed by year in the catalogue by Reeds (1937). By 1935, the American Museum's meteorite collection remained one of the largest in the world.

<<< Fig. 7: Decadal growth of the AMNH meteorite collection. >>>

The Reeds catalogue contained 3744 specimens, 246 of which had been exchanged (de-accessioned), for a total of 3,498 specimens. Of the 3744, the catalogue listed 548 individual falls and finds, two of which had been exchanged in their entirety. The nomenclature used in Reeds' catalogue is that of the English chemist, petrologist and mineralogist George Thurland Prior (1920), consistent with the catalogue of the British Museum (Natural History) (Prior 1923), where Prior (1862-1936) was Keeper of Minerals from 1887-1927. Reeds was assisted by Adam Brückner, who in 1914 started the meteorite card system, with duplicate card stacks ordered alphabetically and by specimen number. This system was improved by Joseph Tyson (assistant from1918 to 1925), and George Pinkley (assistant from 1928 to 1932), who re-weighed all the smaller specimens, in grams.

On October 1, 1935, the new Hayden Planetarium opened, and the entire meteorite collection was transferred to the new Astronomy Department and Hayden Planetarium, under Curator Clyde Fisher (1878-1949; Shelby Cty. www 2005). The 77th St. entrance, where the big irons rested, became redundant, and was closed due to lack of funds once the Roosevelt Memorial Hall (Rotunda) on Central Park West was completed in 1936. The Report of the President (AMNH 1935, p. 8) describes the Copernican hall on the first floor of the Planetarium: "In the corridor surrounding this hall are various other exhibits, including ... a collection of meteorites including 548 falls".

Reeds joined the Astronomy Dept. as Research Associate in Meteorites in 1935, while remaining Curator of Geology and Invertebrate Palaeontology. In the next year Frederick H. Pough, Ph.D. (b. 1906) joined the Museum as Assistant Curator in the Department of Mineralogy. The mineral collection had been managed in that Department since 1891, under Curator and Chairman (in 1935) Herbert P. Whitlock (1868-1948). In 1937, Reeds resigned, and Pough became a Research Associate in Astronomy, while remaining Assistant Curator in the new Department of Geology and Mineralogy, under Whitlock (AMNH 1937, 1938). Invertebrate Palaeontology had now separated from Geology, and after Whitlock's retirement in 1941, Pough became Acting Curator of the new Geology and Mineralogy Department, and Curator in 1943. A year later, the mineral collection became part of Geology and Palaeontology, chaired by the great evolutionary theorist and vertebrate palaeontologist Dr. George Gaylord Simpson (1902-1984). Pough became Curator of Physical Geology and Mineralogy in his department.

While the study and display collections were housed in the Hayden Planetarium, correspondence reveals that new accessions of meteorites were curated by Pough. In 1940, the great polar explorer Mr. Lincoln Ellsworth (1880-1951) presented a 525 lb. Gibeon specimen, which went on immediate display. In 1941, twelve new meteorites were added, and a renovation of the Planetarium display was begun. In subsequent years, the meteorite collection grew slowly (Fig. 7), as Dr. Pough concentrated on the gem collection until he left the Museum in 1952.

The Modern Era

The collection did not stand quiescent from 1937 to 1953, but new meteorites in this period appear to have been kept separately from those in the collection described by Reeds (1937). In May 1953, Brian H. Mason (b. 1917), Ph.D. arrived as the new Curator of Mineralogy, joining Simpson's department. Also in 1953, the Planetarium "asked to be relieved of curation of the meteorite collection" (Mason and Nathan 2001, p.39). Brian Mason was an academic geologist, originally from New Zealand, who had since 1946 been Professor of Mineralogy at the University of Indiana. Mason took his Ph.D. under the father of modern geochemistry, Victor Moritz Goldschmidt (1888-1947) (Goldschmidt 1954; Mason 1943, 1992). Mason's *Principles of Geochemistry* (1952), sold over 60,000 copies in four editions.

Mason reports finding the meteorite collection in boxes and trays. While continuing his work on terrestrial geology, particularly the Southern Alps of New Zealand, he focused on meteorites at a very exciting time, and built the collection to ~4000 specimens (counting many fragments of some individuals, and 442 tektites), representing 850 different individual meteorites (Mason 1964). Mason concentrated on detailed chemical analysis of the meteorites in the collection, and making specimens available to outside researchers. He was an excellent petrologist, who would even, when describing Antarctic meteorites later in his career, determine plagioclase content of feldspar crystals by measuring their optic extinction angles using a universal petrographic microscope stage. He also pioneered efficient methods of obtaining the fayalite content of olivine, to assist in rapidly re-classifying the chondrites in the meteorite collection.

Meteorites do not figure prominently in the AMNH Annual Reports of this period, even as the Planetarium "prepared for the tremendous increase of interest generated by the arrival of the Earth satellite era" (Sputnik), in the International Geophysical Year (AMNH 1958). In 1960, Simpson moved to Harvard, the Department of Geology and Palaeontology fissioned, and a new Department of Mineralogy was established with Mason as Chairman and Curator. The new Department of Invertebrate Palaeontology was to grow much faster than Mineralogy.

The collection's holding of unique individual meteorites grew respectably in the Mason years (Fig. 7), partly through the acquisition of small samples of ordinary chondrites for research. Mason concentrated on scientific work, such as his service on the first Working Group on Meteorites, convened by UNESCO in 1964 (Mason 1997), and discovery of the mineral sinoite, Si_2N_2O in the Jajh deh Kot Lalu meteorite (Anderson *et al.* 1964). He was rewarded with the Leonard Medal of the Meteoritical Society in 1972. While attending his very first annual Meteoritical Society meeting (Tempe, Arizona, 1964), Mason got a call from the Museum's director, Thomas Nicholson. The Hall of Minerals and Gems had been burgled by the infamous Jack Roland Murphy, a.k.a.

'Murph the Surf' (Preston 1986). Edward (Ed) Anders reportedly asked, "Did they take any meteorites?", and, hearing "no", said "Well, that's good" (Mason 1996b).

Mason was the first curator to actively collect meteorites in the field, as a result of the increasing need for research specimens stimulated by the Apollo programme. Mason and Edward P. Henderson, Curator at the Smithsonian Institution, went to Australia in 1963 and 1964, collecting pieces of Dalgety Downs, Wolf Creek, and numerous tektites (Mason & Nathan 2001). Mason left the tektite collection "fairly comprehensive, containing specimens from the major strewnfields except that of the Ivory Coast in West Africa" (Mason 1964, p. 39). At the time, Mason was a one-man Department of Mineralogy. Meteorite collecting trips to Australia in 1965, 67, 69, 73, 78 and 79 and to Pueblito de Allende in 1969, occurred after Henderson had lured Mason to the Smithsonian in 1965 to join a larger department with generous grants for equipment (Mason and Nathan 2001, p. 55). Mason reports (Mason & Nathan 2001, p. 68) that his experience with the Wallace endowment fund for research at AMNH inspired his 1990 establishment of the Canterbury/Westland Science and Technology Trust for the Canterbury Museum in Christchurch, New Zealand. Mason resigned in May of 1965, but continued as a Research Associate at AMNH for several years.

On Mason's resignation, the South African geologist D. Vincent Manson (1936-1999) was hired as Assistant Curator of Mineralogy. Continuity was provided by departmental secretary Mrs. Gertrude Poldervaart (1917-1991), and Mr. David M. Seaman (1907-1999), who served as scientific assistant from 1958 to 1974. Manson concentrated on the mineral collections, but continued accessioning new meteorites (Fig. 7). New exhibit halls, particularly for gems, were to become his focus. Work on the Lindsley Hall of Earth History proceeded in 1967, and the famous old Morgan Hall of Minerals on the fourth floor, which had opened in 1916, was closed in 1968. Planning for the new mineral and gem halls proceeded with due deliberation. Manson became Consultant on the new Hall in 1974, leaving the Department in the administrative control of AMNH Deputy Director for Research, Jerome G. Rozen, Jr. In this period Andrew Davis, now at the University of Chicago, recalls borrowing pallasite samples for his thesis research, since pallasites were rare in the Yale collection. He was allowed to remove virtually all the AMNH pallasites in a suitcase, but they all made it back safely.

In 1973-74, the administration decided that a single-curator department was no longer viable, and that both a mineralogist *and* a meteoriticist were needed, along with support staff. Following a search, Dr. Martin (Marty) Prinz (1931-2000), formerly of the Institute of Metoritics at the University of New Mexico, and an AMNH Research Associate since November 1972, became Chairman and Curator in 1976. Simultaneously, the Department of Mineralogy became the Department of Mineral Sciences. On May 21, 1976, the Museum opened new, permanent exhibition halls of gems, minerals, and meteorites (described later). This triumph was the "culmination of many years of effort by D. Vincent Manson" (AMNH 1976, p.20). Manson went on to a distinguished career with the Gemological Institute of America. Dr. George Harlow (b. 1949), who had earned his Ph.D. with Eric Dowty at Princeton, was hired in 1976 as Assistant Curator to take over the mineral and gem collections. Prinz and Harlow proceeded to make the fledgling Dept. of Mineral Sciences a centre of meteoritic and petrological science.

The meteorite collection had continued to grow steadily since Mason's departure. In the many years Martin Prinz curated the collection, it grew by about 550 catalogue numbers in 378 different meteorites, of which 279 were new finds or falls. In 2000, the collection contained a total of about 5,000 specimens, representing 1,255 individual meteorites. In this period, exchanges with other museums and with private dealers continued to be the dominant method of acquisition. The focus in the later years of the twentieth century was on obtaining new and scientifically important, "interesting" new specimens: carbonaceous and enstatite chondrites; iron meteorites with silicate inclusions; mesosiderites and pallasites; eucrites, howardites and diogenites (thought to be from the differentiated asteroid Vesta); meteorites now recognized to be from Mars; chondrites of low petrological grade (unequilibrated, meaning least altered by processes on parent asteroids); and rare achondrites such as brachinites and ureilites. Prinz's sentiment was: "We're here to get this collection out into the research world, not mouldering in cabinets" (J. Delaney, pers. comm.). Prinz initiated cooperation between museums, to promote the worldwide distribution and exhibition of specimens. He was also more careful with loans, monitoring just how much was needed for destructive analysis by his colleagues.

The collection today owes a lot to Prinz's good relationship with a number of prominent collectors and dealers. Too numerous to mention evenhandedly, these included: Allan Lang, Darryl Pitt, Ray Meyer, Michael Casper, and, later, Marvin Kilgore. Some were particularly generous in donating material, or yielding the advantage in an exchange. Prinz had a warm relationship, with Jim DuPont (1912-1991), of Watchung, NJ, and exchanged a great many specimens with him. DuPont's collection was said to be the largest held by any individual in the world, at the time of his death in 1991. The collection eventually went to the Planetary Studies Foundation of Algonquin, Illinois.

The Prinz era (1976 - 2000) saw a tremendous, world-wideincrease in the perceived value of meteorites, and concomitant difficulty in building collections. The lamentations of Bement (1885b) regarding cost, quoted above, remain true. At the same time, the amount of a particular meteorite necessary for many types of scientific analysis decreased markedly, as a result of increasingly accurate analytical techniques: the electron microprobe (EMP), the secondary ion mass spectrometer (SIMS), the scanning electron microscope (SEM) and, most recently, ion-coupled plasma mass spectrometry (ICPMS). Science-driven collecting became paramount in this era.

Meteorites on Display

Until the 1940s, much of the research collections were kept in drawers in the exhibition halls. Most of the meteorites were part of a "study collection", distinct from the large display specimens. The study collection, consisting of six cases, was first housed in the 77th Street main entrance of the museum, after 1902 in the fourth floor mineralogy hall (Gratacap 1902), and in 1906 it appears in the adjacent Geology Hall. The large irons remained in the Foyer: three Cape York, Willamette, with Cañon Diablo (2,391 kg), Brenham (165 and 115 kg), Forest City (165 kg), and Long Island (189 kg) (Hovey 1907). An iron cast (hollow) of the famous Tucson ring meteorite, presented by the Smithsonian, was also on display (Osborn 1911, p. 44).

In 1901, the Ward-Coonley Collection of meteorites was deposited with the Museum, in seven cases in the Geology Hall (Fig. 8; Gratacap 1906; Osborn 1911). In about 1600 specimens, it consisted of 603 of the 677 meteorites then known, according to

Brezina, whose collection at the Vienna Museum held only 557 (Gratacap 1906). Henry A. Ward (1934-1906) was the very colourful scientist, explorer, and founder in 1862 of Ward's Natural Science Establishment in Rochester, New York (University of Rochester 2005; Ward 1948). Ward had studied with Agassiz at Harvard in 1854, and financed his later studies in Paris by selling fossils. An admirer judged that "internally he is composed of raw-hide, whale-bone and asbestos" (Harvard Magazine 1999). He taught at Rochester for several years, then became principally a supplier of geological samples. After selling his great mineral collection in 1893, he became consumed by meteorites and, with his wealthy wife Lydia Avery Coonley's assistance, assembled what is still the largest meteorite collection ever assembled by a single person. In the early 1900s, he prepared to sell the collection, and several printed catalogues were prepared (e.g., Ward 1901, 1904c). Curator L. P. Gratacap wrote a glowing description of the collection, perhaps to influence its eventual disposition: "No one in the United States has exhibited greater perseverance and a more boundless, almost reckless, enthusiasm in this work of collecting meteorites than Professor Henry A. Ward. His audacity and zeal have gone hand in hand with a keen scientific sense of ... their study... it would be safe to predict his first arrival at the scene of any new meteorite's fall today" (Gratacap 1906). All was for naught. Legend has it that Henry Ward was sleeping off a transitory illness on a bench in Gratacap's mineralogy lab, at the latter's insistence. Awakened after falling to the floor, he decided to take the overnight train to Buffalo. At the time, horseless carriages were allowed a top speed of only 5 mph. The next morning, Ward became the first person to be killed by an automobile in that city (the first ever was in New York City in 1899). The Ward-Coonley Collection remained at the AMNH through 1911. After the AMNH failed to exercise its option to purchase the collection, and the Smithsonian failed to raise the necessary funds, Mrs. Coonley sold it for $80,000 to the Field Museum of Natural History in Chicago in 1912, where it remains (Field Museum, 2005). Oliver Cummings Farrington (1864-1933), Curator at the Field, could correctly state that from 179 individuals in 1895, to 251 in 1903 (Farrington 1903), the Field's was now the "most representative series of meteorites in the world" (Farrington 1915, p. 225). The Field Museum continues to be an important repository for, and site of, scientific research, although few meteorites (or minerals) are currently on display, to the detriment of public education.

<<< Fig. 8: The Ward-Coonley Collection, at AMNH. (Gratacap 1906) >>

In 1913 the study collection cases were moved to the south end of the Geology Hall. All the smaller irons were polished and etched, and many were probably treated to prevent rust (Reeds 1937). The study collection remained in the Geology Hall until the Hayden Planetarium was built, to the northeast of the museum. All the meteorites were transferred to the Department of Astronomy in the Planetarium on October 1, 1935. The Planetarium was effectively built 'around' the largest meteorites. Smaller specimens were displayed on the main floor in cases, while larger ones rested upon special bases in the open (Fig. 9). While much of the collection was removed from display in 1953, the Cape York meteorites, Willamette, and other large meteorites remained in the Planetarium. Sometime during this period, Ahnighito was painted black to hide a thin patina of rust, and make it look more like a "meteorite". In 1958, the Toledo Scale Company donated a giant scale upon which Ahnighito was mounted in the Planetarium. Its definitive weight was 68,080 lbs (30,875 kg). Mason (1996b) notes that Peary's daughter Josephine attended the official weighing.

<<< Fig. 9: Map of Hayden Planetarium main floor, (Reeds 1937) >>>

The modern era of meteorite display begins on May 21, 1976, when a permanent, three-part exhibition opened, consisting of the Harry Frank Guggenheim Hall of Minerals, Morgan Memorial Hall of Gems, and Arthur Ross Hall of Meteorites. Case displays of meteorites were moved from the Planetarium to the vestibule of the new Mineral Hall in the southwest corner of the Museum's first floor. It was apparent that more space was necessary for the meteorites, given their increasing scientific importance and public appeal.

Plans for a new, expanded Arthur Ross Hall of Meteorites were begun in 1979. The vestibule leading to the mineral Hall would be expanded into a hexagonal room (about 2200 sq ft) occupying the first floor interior of the southwest tower of the museum (Fig. 2). After some discussion with the Planetarium, it was decided that Ahnighito would be moved. Initial plans had Ahnighito to one side, with a 'tail' of display elements curving from it, however the underlying structure of the building forbade this configuration. Photos on display in the current Hall document the transport of Ahnighito by a giant crane up through the roof of the Planetarium, then again on steel rails, to become the centerpiece of the Hall. Immediately, Curator Marty Prinz directed sand-blasting to remove the black paint. Ahnighito rested on six pillars that descend through the basement to bedrock, with a mirror on the ceiling above. A total of 125 specimens were displayed, largely organized according to meteorite classification. The large irons Gibeon, Canyon Diablo, Knowles, Henbury, Woman, Dog, Guffey were mounted on iron posts (Fig. 10). Three lunar samples, encapsulated in acrylic blocks, were loaned by NASA to complement the meteorites (Apollo 14 #14305,30 KREEP basalt; Apollo 16 #60015,179 anorthosite breccia; Apollo 17 #70035,57 mare basalt).

<< Fig. 10: The "first" Ross Hall of Meteorites, 1981.>>

Through the generosity of New York philanthropist Arthur Ross, and curated by Martin Prinz, the new Arthur Ross Hall of Meteorites opened on 1981. The opening was preceded by a "highly publicized one-day Arthur Ross Meteorite Symposium in which eight outstanding scientists from across the country informed a capacity audience of exciting new findings in this field, which includes Planetology" (AMNH 1981; Fig. 11). Each spoke for an hour. A special supplement to the April issue of *Natural History* magazine carried four pieces on meteorites, but not the CalTech cosmochemist Prof. Gerry J. Wasserburg's talk entitled "Stardust Memories", because he refused to allow his English to be edited! A black-tie opening celebration was held in the new Hall (AMNH 1981). Other outstanding scientists saw the Hall when the Meteoritical Society held its 49th annual meeting at the AMNH in 1986, attended by 315 participants. A highlight was the banquet held under the full-size blue whale model in the Hall of Ocean Life.

<< Fig. 11: Participants in 1981 Ross Symposium on Meteoritics. >>

Changes and temporary exhibits in the Hall of Meteorites included addition of a theatre in 1990, featuring footage of meteorite investigators and planetary scientists George W. Wetherill (Carnegie Institution of Washington), Eugene (Gene) M. Shoemaker (1928-1997), Walter Alvarez (b. 1940), Prof. Peter Schultz (Brown Univ.), and Martin (Marty) Prinz. A complete revision of text occurred in 1998. Special temporary displays included the Peekskill car which is famous in the U.S:

On Friday, October 9, 1992, the Peekskill meteorite (H6) streaked from Kentucky to New York in a spectacular multi-part fireball for about 40 seconds in the evening sky during football season in the era of the film and video camera. It made a "crackling sound like that of a sparkler", and from 16 video records, a good orbit was calculated, the fourth ever known (Beech, 2005). The single recovered fragment (12.4 kg; Wlotzka 1994), about the size of a football, slammed through the trunk of Michelle Knapp's red Chevrolet Malibu (Langheinrich 2005), making a slight depression in the asphalt driveway beneath. Associate Curator Edmond Mathez, and David Walker of Columbia/Lamont-Doherty Earth Observatory, were contacted first. Walker was the first to recognize it as a meteorite, and identify it as an H chondrite (Walker, pers. comm.). Martin Prinz went to Peekskill the next day. A few days later Mike Weisberg and Scientific Assistant Steven Tolliday went with Prinz to negotiate purchasing the meteorite, and confirm the identity and type of the fragment (J. Delaney, pers. comm.). The entire mass was purchased by collectors Allan Lang, Ray Meyer, and Marlin Cilz, for $78,000, including the car (Norton 1998; Cilz 2005; Grady 2000). AMNH #4834 is a 7.8g piece acquired on October 10, 1992. A larger, 900g whole cross-section slice (~2cm thick, AMNH #4896), was not acquired until 1995, by exchange for part of the Kyushu, Japan, meteorite. The Kyushu specimen is now in the city where it fell in 1886 (Lang 2005). Six plaster casts of the whole specimen were made, painted to match the red streaks from the car on the original. One is in the AMNH collection. The red car came to the Museum as a temporary exhibit in 1993, courtesy of its owner, Allan Lang.

A second special exhibit presented Wethersfield 1 and 2. In 1981, the meteorite Wethersfield 1 had fallen on a house roof in Wethersfield, Connecticut. In 1982, less than two miles away, Wethersfield 2 fell through the roof of Mr. and Mrs. Robert Donahue's house. With the collaboration of the Smithsonian Institution and the Donahues, and the generosity of Arthur Ross, a temporary exhibit was installed to tell this fascinating story. Unfortunately, no samples of either meteorite are in the AMNH collection.

On June 9, 1999, the Museum opened the magnificent new Gottesman Hall of Planet Earth, which exhibits several meteorites in the context of Earth's origin. This Hall is part of the new Rose Center for Earth and Space, replacing the Planetarium building and containing a spectacular new Hayden Planetarium and Cullman Hall of the Universe. Although it is part of the meteorite collection in the Dept. of Earth and Planetary Sciences, the Willamette meteorite is ensconced prominently on the first floor of the new Hall of the Universe, in the Rose Center (Fig. 6). A fine large slab of the Esquel pallasite was acquired at auction, and is displayed nearby (AMNH #4972). In 2002 a fourth lunar rock (mare basalt, Apollo 15, #15475,134) was loaned to the Museum by NASA for display in this Hall, bringing the total number of Apollo lunar samples on display to four, more than anywhere else except the Smithsonian.

Early in the 21st century, Arthur Ross decided that his Hall of Meteorites required updating, particularly given the spectacular success of the new Rose Center. At that time Martin Prinz was gravely ill with cancer, and the Museum undertook a search for a new meteorite curator. Dr. Prinz died on Dec. 16, 2000 (Keil & Weisberg 2001). On July 1, 2001 Dr. Denton S. Ebel, Research Scientist at The University of Chicago, was hired as Assistant Curator. He very soon set to work planning a new Hall of Meteorites. On a November weekend in 2001, a group consisting of John Wood (Harvard), Gary Huss (Arizona State U.), David Walker (Columbia/LDEO), Carlé Pieters (Brown U.), Edmond

Mathez (AMNH), and Harold Connolly (Kingsborough, CUNY) was assembled to brainstorm on content. The new Arthur Ross Hall of Meteorites opened on September 20, 2003 (Ebel and Boesenberg 2004).

The focus of the Hall is: What do meteorites tell us? - about solar system origins, planet formation, and the history of a dynamic solar system (through impacts). A total of 160 specimens are displayed. All the favourite irons except Knowles stand alone where they can be touched, as well as Estacado (H6, 117 kg). Other notable samples include the main mass of the Johnstown diogenite, a back-lit slab (~91 x 36 cm) of the Esquel pallasite, and five Martian meteorites. A vial of presolar nanometric (about 1000 atoms per grain) diamonds donated by Roy S. Lewis, who pioneered their extraction from chondrites at the University of Chicago, is featured in the section on solar origins. Impacts are explored with a scale diorama of Arizona's Meteor Crater. Shale balls, lechatelierite (natural silica glass), shocked sandstone, and other objective evidence of that impact (Nininger 1956) were acquired to illustrate impact phenomena[1]. This is in historical resonance with the American Museum's temporary exhibition, in 1914, of the Daniel Moreau Barringer (1860-1929) collection of Meteor Crater material (Barringer 1914)[2].

In conjunction with the new Hall, funding was obtained from NASA to create a Teacher's Guide to the new Hall of Meteorites, available to all through the World Wide Web. Regular workshops are held, to help educators in using the Hall for science education. The new Hall provides an entry point for high school level chemistry teachers, in particular, by exploring the similarity of chondrite bulk chemistry to the sun's composition, and the differentiation of planets. The Meteorite Hall serves as a bridge between the Hall of Planet Earth and the Hall of the Universe.

Meteorite Science

The contribution of any meteorite collection to scientific progress is directly proportional to curatorial interest. In the youth of the collection, under the direction of Curators Whitfield, Gratacap, Hovey and Reeds, science and curation centered on description and classification of specimens. The next curator to take a special interest in meteorites was Mason. He had left New Zealand for Norway in 1940, to study with V.M. Goldschmidt, inspired by the latter's table of cosmic abundances based on analyses of meteorites and solar and stellar spectra (Marvin 1993, p. 274; Goldschmidt 1937). Mason's early work was determining the geochemical affinity of tellurium, by chemical

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[1] These specimens were originally collected by the great collector and public educator Harvey Harlow Nininger (1887-1986) (Nininger 1956, 1971). The Nininger collection was rich in North American falls (150) and finds (~530; Nininger 1972, p. 205), nearly as many individual meteorites as were in the U.S. National Collection at the time (1958) about 30% of the Nininger collection was sold to the British Museum (Natural History). Following an outcry by U.S. meteoriticists, the main part of the Nininger collection (684 individuals) was purchased by the Center for Meteorite Studies at Arizona Sate University (ASU) in 1960 (G. Huss, pers. comm., 2005). Carleton B. Moore built up this collection over many years, with purchase of a collection by Charles Upham Shepard (1804-1886; SI-www 2005) from Amherst College in 1980, and including trades with Prinz at the AMNH (Lewis et al. 1985). The ASU collection is presently larger than that of the AMNH in the number of individual meteorites represented (L. Leshin, pers. comm., 2005).

[2] The story of Barringer's crater is well told in several sources (e.g., Hoyt 1987).

analysis of meteoritic olivine [$(MgFe)_2SiO_4$], nickel-iron, and troilite (FeS) (Mason and Nathan 2001, p. 26). At the AMNH, he immediately began to focus on methods for the better chemical classification of chondritic meteorites, noting the imprecision of "stone" and "chondrite", and the difficulty of applying Prior's classification scheme by chemical analysis to an entire collection.

Science, and meteorite studies, entered an entirely new era after World War II, particularly the study of chondrites. The Report of the President for 1955 notes: "We have now reached a position where the strengthening of our scientific departments, with greater emphasis on research, must be seriously considered" (AMNH 1955, p. 4). Mason reports an early communication from cosmochemist Harold C. Urey (1893-1981) of the University of Chicago, requesting research material after refusals from the British Museum and Chicago's Field Museum. At the former, curator Max H. Hey's (1) policy on meteorites was "Get them, and keep them", and Sharat Kumar Roy (1898-1962) of the Field did not want to render incorrect his just-published catalogue reporting meteorite masses! Mason's thinking was: "the more research on the meteorite collection the better" (Mason & Nathan 2001, p. 41). To increase the research value of the collection, Mason endeavored to better characterize the mineralogy and bulk chemistry of the meteorites. In 1956 he hired Birger Wiik, an analytical chemist from the Geological Survey of Finland. Wiik had worked with Urey in 1954. Following the flight of the Russian satellite Sputnik-I in October 1957, they obtained funding from the National Science Foundation to do the work. Wiik and Mason described about 50 meteorites over the next ten years (e.g., Mason 1963a; Mason & Wiik 1962), and divided the carbonaceous chondrites into three subgroups (Wiik 1956). Mason rightly reports: "During my lifetime, meteorites have gone from being curios stashed away by museum curators, to being objects of unique significance for deciphering the origin, age, and evolution of the solar system" (Mason & Nathan 2001). In 1992, Mason was to complete the biography of Goldschmidt begun by one of this author's earliest mentors, Gunnar Kullerud (1921-1989; Albright et al. 1990). Mason also taught a graduate course in meteoritics and geochemistry at Columbia University, taken by Edward Anders in 1953, and Billy P. Glass in 1960, among many others (Marvin 1993, p. 274).

Important loans of meteoritic material during Mason's tenure include those to Urey, who with Wiik determined bulk compositions of chondrites. In 1959, Paul Ramdohr (1890-1985), recently retired as Professor of Mineralogy at U. Heidelberg, went to the Geophysical Laboratory in Washington, and studied opaque minerals in meteorite thin sections. Mason provided the samples that led to several papers and the book *The Opaque Minerals in Stony Meteorites* (Ramdohr 1973). He also translated several chapters, and presented Ramdohr with the Leonard Medal of the Meteoritical Society, in Heidelberg in 1979 (Mason 1996a). In 1960, Bartholomew Nagy and Douglass J. Hennessy of Fordham University, with Warren G. Meinschein of Esso Research Labs, were provided with ten grams of the Orgueil meteorite. This sample produced an early, definitive identification of organic compounds in carbonaceous chondrites (Meinschein *et al.* 1963; Mason 1963b). Headlines about "life in meteorites" led to an inconclusive 1962 symposium (NYAS 1963), moderated by Harold C. Urey, at which Mason explained how easily meteorites can be contaminated by terrestrial material (e.g., pollen. Despite rapid consensus against extraterrestrial life in meteorites, the controversy led to the quarantine of the Apollo astronauts, and provided early fodder for the "field without a subject" called ‘exobiology’, currently known as ‘astrobiology’. In 1964, Mason supplied meteorite specimens to Bob Fleischer, Buford Price and Bob Walker, from the General Electric Research Center in Schenectady, New York, to study fission tracks produced by the decay of radioactive xenon, for age-dating of meteorites.

The origin of chondrules became a point of conflict between Mason and Urey. Mason argued (1960a,b) that chondrules in ordinary chondrites form by *in situ* solid-state metamorphic recrystallization of carbonaceous chondrite material, “chondrules of chlorite”. Urey (1961) replied that “water-carrying organic compounds” infiltrated chondrites, oxidizing metal to magnetite or sulphide, depositing carbon compounds and sulphates, removing potassium and sodium, and obliterating chondrule textures. This kind of spirited controversy became the life-blood of modern meteorite studies, resolvable only by detailed chemical and isotopic analysis of carefully documented meteorite specimens at the microscopic level. Mason published an influential book on meteorite science (1962), shortly before his departure for the Smithsonian. Mason’s successor, Manson, began the “use of computers for data retrieval and multivariate statistical analysis” (AMNH 1966). In 1968, Manson was “... continuing his investigations of empirical chemical variations in meteorites and terrestrial rocks. ... highly successful new methods of computer analysis of geologic data have been developed.... Progress has been made to the point where a remote terminal in the Museum with direct connections to a computer is now operating successfully” (AMNH 1968, p. 49). By 1973, “Mineral inclusions in diamonds continued to be the principal research topic of Dr. D. Vincent Manson ... working with Dr. Martin Prinz” (AMNH 1973). Prinz and Harlow became the nucleus of the new Dept. of Mineral Science in 1976.

Research Associates working on the meteorite collection in the Martin Prinz era (1976 - 2000) have included Klaus Keil (1977-1999; then at U. New Mexico’s Institute for Meteorite Studies), Eric Dowty (1977-1984, Princeton), C.E. Nehru (1975-present; Brooklyn College), Roger Hewins (1977-80; Rutgers), R. Keith O’Nions (1980; then at Columbia/Lamont), and Robert T. Dodd (1984-1999; SUNY Stonybrook). Prinz’s tenure is notable for numerous collaborations with scientists worldwide, particularly in Europe (e.g., Gero Kurat in Vienna), and Japan, resulting in his authoring or co-authoring more than 135 papers in refereed journals. Meteorite studies ranged over the entire collection.

Immediately upon becoming curator, Prinz approached NASA for support of collaborative studies on meteorites and for acquisition of an electron microprobe (EMP). This was probably the first facility of its kind in New York City (AMNH 1977). Achondrites (mesosiderites, eucrites, diogenites, SNCs, lodranites) were the focus of early work, including the meteorites Chassigny, Serra de Magé, Johnstown, Chervony Kut, Emery, and Lodran. Mesosiderites were found to be extraterrestrial impact melt breccias. Study of achondrites was seen as the key to the “new field of comparative planetology” (Prinz, in AMNH 1979). Thomas R. Watters, then a graduate student at Bryn Mawr, began critical work on aubrites (Watters & Prinz 1979). John L. Berkley, G. Jeffrey Taylor, and Klaus Keil worked with Prinz and mineralogist George Harlow on a model for the origin of ureilites (Berkley *et al.* 1980). Harlow, Prinz and O’Nions studied silicate inclusions in irons.

Dr. Prinz nurtured the careers of several prominent meteoriticists, as well as collaborating extensively with mineralogist Harlow (e.g., Harlow *et al.* 1982). Michael K. Weisberg began work at AMNH while a graduate student at Brooklyn College in 1984, became Scientific Assistant in 1986 - the first dedicated to the meteorite collection - then Research Fellow in 1991, obtaining his Ph.D. in 1996, and becoming Assistant Professor at Kingsborough College, City University of New York (CUNY) in 1999. Craig Johnson became a Research Fellow in 1989, then Curatorial Fellow in 1991, supervising the electron microprobe until 1992. Robert (Bobby) Fogel joined the Department in 1990 as a Research Fellow, and continued as a Research Scientist, before taking a post at NASA headquarters in 2005. Richard Ash was a postdoctoral Fellow in 1995-96, and Joseph Boesenberg became Scientific Assistant (meteorites) in 1992. Numerous Brooklyn College students passed through, pursuing projects with Dr. Nehru. Mike Weisberg recalls that Prinz used a “horizontal filing system” to keep track of so many ongoing projects. His enthusiasm was such that everyone would have to drop what they were doing whenever a new, exciting phenomenon was discovered. Spending all-nighters on the electron microprobe, Mike recalls Prinz’s phone calls at 3:30am, “I couldn’t sleep; you have to tell me the results”.

Jeremy S. Delaney arrived as a NASA-funded post-doctoral fellow, and worked with Martin Prinz at AMNH from 1979 to 1987, before moving to Rutgers University. He started work in mesosiderites, but turned to howardites to understand the silicate inclusions. Finally, he took over all the achondrites, leaving Prinz to investigate ureilites, silicate inclusions (in irons), primitive achondrites, and the newly recognized acapulcoites. Winonaites were recognized as a separate group (Prinz *et al.* 1980). Delaney recalls advice from Prinz along these lines: “The way the meteorite business works is there are lots and lots of weird meteorites out there that have never been looked at properly, and all you have to do is study one of these exotic groups, and that makes you the world’s expert” (Delaney, pers. comm., Jan-2005). There were always bull sessions going on, with particular focus on the latest new meteorite. Jerry continues: “I do believe Marty has a co-authorship on just about every type of meteorite in existence - at minimum an abstract”. One year in the mid 1980s, the Prinz group presented ten abstracts at the annual Lunar and Planetary Science Conference in Houston. The petrographic and chemical descriptions of anomalous objects stimulated other meteoriticists to perform more detailed study of those objects. Delaney describes this role of catalyzing interest of others as a singular contribution: “Marty’s insatiable curiosity led to pioneering studies that excited the community to want to take a better look, leading down new paths, and ultimately to an awareness of groups, and their relationships, rather than just weird, irrelevant things. This is still unfolding.” In 1989, Delaney gave a keynote address at the annual meeting of Japan’s National Institute for Polar Research (NIPR), following identification of the first Antarctic lunar basalt meteorite (from Elephant Moraine, EET 87521, Delaney 1989). Paul Warren also published on the same rock, in the same month (Warren & Kallemeyn 1989), so they formed a consortium to study it in concert. Prinz recognized the importance of new techniques. He made it possible for Delaney to begin work on the synchrotron at Brookhaven National Laboratory on Long Island. Meteorites from AMNH were used to do the first calibrations of the Brookhaven beamline X26, for x-ray fluorescence microanalysis. XRF techniques are more sensitive than ion probe for analyzing rocks for hard-to-ionize trace elements.

In 1994-95, the Department of Mineral Sciences became the Department of Earth and Planetary Sciences, a name that “more accurately reflects the expertise and range of scholarly activities of the Department’s curators and research scientists, and further emphasizes the importance of the Earth sciences in natural history" (AMNH 1996, p. 24). A major upgrade of the laboratory and office facilities was completed under the new Chairman, Edmond Mathez. Research Scientist Robert Fogel received a NASA grant to study silicate melts under low partial pressures of oxygen, thought to be analogous to certain melted rocks found in meteorites (Fogel 1994). Research Associate Weisberg was invited to give a keynote address at the annual meeting of NIPR in Japan, describing his work on CR chondrites (Weisberg et al. 1995).

The turn of the millennium was a bittersweet time for meteorite science at AMNH. Ill with cancer, Martin Prinz became Curator Emeritus in 1999. He was honored at a special reception at the Chicago meeting of the Meteoritical Society that year, while a search was in progress for his successor. The magnificent new Hall of Planet Earth, and Hall of the Universe, both displaying meteorites in the context of Earth's origin, opened in 1999. The Museum also established a new Department of Astrophysics, with Dr. Michael Shara appointed as Curator-in-Charge and Dr. Mordecai-Mark Mac Low as Assistant Curator. Astrophysicist Neil DeGrasse Tyson (Ph.D.) became the first Frederick P. Rose Director of the Hayden Planetarium. Meteoritics is, of course, the link between astrophysics and planetary sciences, so this new direction for the AMNH has opened new vistas for collaborative science. The first joint paper between these groups appeared in 2004, linking chondrule phenomenology with astrophysical models to address chondrule formation (Joung *et al.* 2004).

Research Tools

Research petrographic microscopes and cutting and polishing equipment have been fundamental to geological research, including meteoritics, for nearly two centuries. They remain so, but micro-analytical scientific instrumentation has become increasingly important in meteorite research, since the invention of the electron microprobe in the 1960s. The Museum obtained a Cambridge Instruments scanning electron microscope (SEM) in 1973 as an interdepartmental facility. An ARL-SEMQ electron microprobe (EMP) was obtained in 1977 with support from NASA. Both these instruments have been upgraded: to a Zeiss SEM in 1990, and to a Hitachi field-emission SEM in 1998; and to a CAMECA SX100 EMP in 1995. Meteorite science contributed strongly to the justification for funding of both these 'bread and butter' instruments for microscopic imaging, and for obtaining the chemical compositions of minerals and glasses on spots smaller than a micrometre in diameter. Harlow brought in X-ray single-crystal and powder diffraction instrumentation from 1977 onward to help augment meteoritic mineralogical studies, as exemplified by studies of pyroxene in achondrites and stony-irons (Harlow *et al*. 1979). In 1996 the IBM Corporation donated a Fourier Transform Infrared Spectrometer, run by Robert Fogel as a joint LDEO/IBM/AMNH facility. This tool enables the micro-analysis of thinly polished slices of glassy objects for their contents of volatile molecules such as H_2O, CO_2, and SO_2. Applications include study of the glass preserved in once-molten chondrules, or in glassy spherules erupted in fire fountains from deep within the Moon when it was young and the mare were forming.

Recent years have seen the rise of electronic communication tools, particularly the World Wide Web, which hold great promise for making collection-based resources accessible. In 1981, Citicorp donated a "Word Processing and Data Base Management" computer system valued at $1.8 million, and by 1982 all the meteorites were on it, as well as ~10,000 of the 40,000 mineral specimens in the Columbia University collection acquired in 1980 (AMNH 1982). The current meteorite catalogue is an electronic database, available via the web. Indeed, the research and public outreach made possible by modern computational and data-handling tools make the mid-1970s ambitions of Manson appear visionary. "Virtual collections", online educational offerings, presentation of current research, and enhancement of specimen research value through digital data such as elemental composition maps of sample surfaces, are all projected to intensify in the decade ahead.

In recent years, Assistant Curator Denton S. Ebel has begun systematic collection of tomographic images of subsections of scientifically important meteorites in the collection. Synchrotron computer-assisted x-ray microtomography, like a CAT scan, yields 3-dimensional maps of meteorite volumes of about one cubic centimetre, or smaller. Typical chondrules are smaller than a millimetre. Each volume element or 'voxel' of the map is about 15 microns (or less) on each edge, and the average density of each voxel is a grayscale value. Mason and Wiik added value to the meteorite collection by meticulous chemical analysis. Tomography is a vital step in accurately characterizing the *textures* of meteorites in 3D. Combined with EMP, SEM and other analytical work on exposed surfaces, tomography has the potential to reveal new information about how chondrite parent bodies accreted, how lithification occurred, and what forces affected chondrules and matrix before and after accretion. The depth of the collection is crucial in applying these tools to compare and contrast the full diversity of extraterrestrial materials. Spectacular suites of images result from all this work, including movies 'flying through' meteorites in miniature, and multi-channel maps of the distribution of elements across square centimeters of meteorite surfaces. Perhaps by displaying these results on the web and in the museum, we can capture the imaginations of the next potential generation to explore the solar system through the scientific study of extraterrestrial samples.

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References

Albright L. F., Gartenhaus S., & Lipschutz M.E. 1990. Memorial of Gunnar Kullerud. *Amer. Mineral.*, **75**, 1451-1452.

AMNH (1870 - 2003) *Annual Report of the American Museum of Natural History*, New York.

AMNH-www (2005) http://www.amnh.org/museum/history/ (accessed 30-Jan-05)

Anderson, C. A., Keil, K., & Mason B. 1964. Silicon oxynitride: a meteoric mineral. *Science*, **146**, 256-267.

Barringer, D. M. 1914. Further notes on Meteor Crater, Arizona. *Proceedings of the Academy of Natural Sciences of Philadelphia*, **LXVI**, 556-66.

Beech, M. (2005) http://leroy.cc.uregina.ca/~astro/mb_5.html (accessed 29-Jan-05)

Bement, C. S. 1885a. Letter to Kunz from Philadelphia, June 5, 1885. Ferdinand Deer Collection of the Historical Society of Pennsylvania, Philadelphia. (cited in Peters & Pearson 1990).

Bement, C. S. 1885b. Letter to Kunz from Philadelphia, September 5, 1885. Ferdinand Deer Collection of the Historical Society of Pennsylvania, Philadelphia. (cited in Peters & Pearson 1990).

Bement, C. S. 1896. Letter to Wolff from Philadelphia, Sept. 10, 1896. Harvard Mineralogical Museum Archives (quote from Peters & Pearson 1990).

Bement, C. S. 1897. *Fourth Rough List of Meteorites.* Privately printed, Philadelphia, 27pp.

Berkley, J.L., Taylor, G. J., Keil, K., Harlow, G.E., & Prinz, M. 1980. The nature and origin of ureilites. *Geochimica et Cosmochimica Acta*, **44**, 1579-1597.

Bevan, A. & DeLaeter, J. 2002. *Meteorites: A Journey Through Space and Time*. Smithsonian Institution Press, Washington. 256pp.

Brown, W. A. 1910. *Morris Ketchum Jesup: A Character Sketch*. Charles Scribner's Sons, New York. 247pp. 2 leaves of plates.

Buchwald, V. F. 1975. *Handbook of Iron Meteorites*. In 3 volumes. U. California Press, Berkeley. 1418pp.

Cassidy, W.A., Villar, L.M., Bunch, T.E., Kohman, T.P., & Milton D.J. 1965. Meteorites and craters of Campo del Cielo, Argentina. *Science*, **149**, 1055-1064.

Canfield, F.A. (1923) The Final Disposition of some American Collections of Minerals. Privately pinted in Trenton, N. J. 20pp.

Cassidy, W.A. 1971 A small meteorite crater: Structural details. *Journal of Geophysical Research*, **76**, 3896-3912.

Cassidy W.A. Renard, M.L. 1996 Discovering research value in the Campo del Cielo, Argentina, meteorite craters. *Meteoritics and Planetary Science*, **31**, 433-448.

Cilz, M. 2005. Quoted on http://formontana.net/cilz.html (accessed 29-Jan-05).

Conklin, L.H. 1998 The Curious Lore of George Frederick Kunz. Part one. *MATRIX*, **5**, 108-114. (also: http://www.lhconklin.com/bio/publications/kunzlore.htm)

Consolmagno, G. 2006. A brief history of the Vatican meteorite collection. *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** (this volume).

Delaney, J. S. 1989. Lunar basalt breccia identified among Antarctic meteorites. *Nature*, **342**, 889-890.

Ebel, D. S. & Boesenberg, J. S. 2004. New Arthur Ross Hall of Meteorites at the American Museum of Natural History. *Meteoritics and Planetary Science*, **39**, 1761-1762.

Farrington, O. C. 1903. Catalogue of the collection of meteorites: May 1, 1903. Field Columbian Museum, Publication 77, Geological Series v. II, No. 2, 79-124. Chicago, USA.

Farrington, O. C. 1915. *Meteorites; their structure, composition, and terrestrial relations.* Published by the author in Chicago. 233pp.

Field Museum 2005. http://www.fieldmuseum.org/research_collections/geology/meteor_col.pdf

Fogel, R. A. 1994. Aubrite basalt vitrophyres: High sulfur silicate melts and a snapshot of aubrite formation. *Meteoritics*, **29**, 466-467.

Goldschmidt, V. M. 1937. The principles of distribution of chemical elements in minerals and rocks. *Journal of the Chemical Society*, 655-673.

Goldschmidt, V. M. 1954. *Geochemistry* (A. Muir, ed.) Oxford Univ. Press, Oxford, England, 730pp.

Grady, M. M. 2000. *Catalogue of Meteorites, with special reference to those represented in the collection of the Natural History Museum, London*. Cambridge U. Press, Cambridge U.K. 689pp., 1 CD-ROM.

Gratacap, L.P. 1902. The collection of minerals. *American Museum of Natural History Guide Leaflet*, **4**, 1-21.

Gratacap, L. P. 1903. *The Certainty of a Future Life in Mars: Being the Posthumous Papers of Bradford Torrey Dodd*. Irving Press, NY, 266pp.
(also at: http://www.gutenberg.org/dirs/1/3/2/8/13289/13289.txt)

Gratacap, L. P. 1905. *The World as Intention; A Contribution to Teleology*. Eaton & Mains, New York. 346pp.

Gratacap, L. P. 1906. The largest American collection of meteorites. Reprinted from the Popular Science Monthly. July, p. 21-28.

Gratacap, L. P. 1909. *The Geology of the City of New York: With Numerous Illustrations and Maps*. H. Holt, New York. x + 232 p. [36] p. of plates.

Gratacap, L. P. 1912. *A Popular Guide to Minerals, with Chapters on the Bement Collection of Minerals in the American Museum of Natural History*. D. Van Nostrand & Co., New York.

Harlow, G. E., Nehru C. E., Prinz, M., Taylor, G. J., & Keil, K. (1979) Pyroxenes in Serra de Magé: Cooling history in comparison with Moama and Moore County. *Earth and Planetary Science Letters*, **43**, 173-181.

Harlow, G. E., Delaney, J. S., Nehru, C. E., & Prinz, M. (1982) Metamorphic reactions in mesosiderites: Origin of abundant phosphate and silica. *Geochimica et Cosmochimica Acta*, **465**, 339-348.

Harvard Magazine. 1999. November-December: Treasure - Sloth and Enterprise. v. 102, no. 2, p. 124. (http://www.harvardmagazine.com/issues/nd99/treasure.html)

Hovey, E. O. 1896. Catalogue of meteorites in the collections of the American Museum of Natural History, to July 1, 1896. *Bulletin of the American Museum of Natural History*, **8**, 149-156.

Hovey, E. O. 1902. Martinique and St. Vincent: A preliminary report upon the eruptions of 1902. *Bulletin of the American Museum of Natural History*, **16**, 333-372.

Hovey, E. O. 1906. The Willamette Meteorite. *American Museum Journal*, **6**, 105-116.

Hovey, E. O. 1907. The meteorites in the foyer of the American Museum of Natural History. *American Museum of Natural History Guide Leaflet*, **26**, p. 1-40.

Hovey, E. O. 1909. The Guffey, Colorado, meteorite. Recent additions to the meteorites in the foyer. *American Museum Journal*, **12**, 257-258.

Hovey, E. O. 1925. A new meteoric stone from Johnstown, Weld County, Colorado. *American Museum Novitates*, **203**, 13 pp. (http://library.amnh.org/pubs/novback.html)

Hoyt, W. G. 1987. Coon Mountain Controversies. U. Arizona Press, Tucson. 442 pp.

Joung, M. K. R., Mac Low, M-M. & Ebel, D. S. 2004. Chondrule formation and protoplanetary disk heating by current sheets in non-ideal magnetohydrodynamic turbulence. *Astrophysical Journal,* **606**, 532-541.

Keil, K. & Weisberg, M. K. 2001. Memorial: Martin (Marty) Prinz (1931-2000). *Meteoritics and Planetary Science*, **36**, 471-472.

Kunz, G. F. 1885. The meteorite from Glorieta Mountain, Santa Fé Co., New Mexico. *Annals of the New York Academy of Sciences*, **III**, 329-334.

Kunz, G. F. 1886. Meteoric iron from Jenny's Creek, Wayne County, West Virginia. *American Journal of Science*, **XXXI**, 145-148.

Kunz, G. F. 1887. On two new meteorites from Carroll County, Kentucky, and Catorze, Mexico. *American Journal of Science*, **XXXIII**, 1-8.

Kunz, G. F. 1890. On five new American meteorites. *American Journal of Science*, **XL**, 312-323.

Kunz, G.F. 1904. Clackamas meteoric iron (Willamette). *Science*, **19**, 108.

Kunz, G. F. & Weinschenk, E. 1892. Farmington, Washington Co., Kansas aerolite. *American Journal of Science*, **XLIII**, 65-67.

Kunz, G. F. & Huntington, O. W. 1893. On the diamond in the Cañon Diablo meteoric iron and on the hardness of carborundum. *American Journal of Science*, **XLVI**, 469-472.

Langheinrich, A. 2005. http://www.nyrockman.com/peekskill.htm (accessed 29-Jan-05)

Lang, A. 2005. Interview in Meteorite Times, July, 2003. http://www.meteoritetimes.com/Back_Links/2003/July/Meteorite_People.htm

Lewis, C. F., Wrona, J. A., and Moore, C. B. 1985. Catolog of Meteorites in the Collections of Arizona State University. Publication No. 20, Center for Meteorite Studies, Arizona State U. 290 pages.

Marvin, U. B. 1993. The Meteoritical Society: 1933 to 1993. *Meteoritics*, **28**, 261-314.

Mason, B. H. 1943. Mineralogical aspects of the system $FeO-Fe_2O_3-MnO-Mn_2O_3$. *Geologiska foreningens i Stockholm Forhandlingar*, **65**, 97-180.

Mason, B. H. 1952. *Principles of Geochemistry* (1st ed.). J. Wiley & Sons, New York. 329 pp. (subsequently 2nd, 3rd, 4th editions)

Mason, B. 1960a. Origin of chondrules and chondritic meteorites. *Nature*, **186**, 230-231.

Mason, B. 1960b. The origin of meteorites. *Journal of Geophysical Research*, **65**, 2965-70.

Mason B. 1962. *Meteorites*. J. Wiley & Sons, New York. 274pp.

Mason, B. 1963a. Olivine composition in chondrites. *Geochimica et Cosmochimica Acta*, **27**, 1011-1023.

Mason, B. 1963b. The carbonaceous chondrites. *Space Science Reviews*, **1**, 621-646.

Mason, B. 1964. The meteorite and tektite collection of the American Museum of Natural History. *American Museum Novitates*, 2190, 1-40.

Mason, B. 1992. *Victor Moritz Goldschmidt: Father of Modern Geochemistry*. Geological Society, London, Special Publications, **4**, 183pp.

Mason, B. 1996a. My life with meteorites, part I. *Meteorite!* vol. 2, #3, 8-11.

Mason, B. 1996b. My life with meteorites, part II. *Meteorite!* vol. 2, #4, 11-15.

Mason, B. 1997. My life with meteorites, part III. *Meteorite!* vol. 3, #1, 24-27.

Mason, B. & Wiik, H. B. 1962. The Renazzo meteorite. *American Museum Novitates*, **2016**, 1-11. (http://library.amnh.org/pubs/novback.html)

Mason, B. & Nathan, S. 2001. *From Mountains to Meteorites*. Geological Society of New Zealand Miscellaneous Publications, **109**, 72pp.

Meinschein, W.G., Nagy, B., & Hennessy, D.J. 1963. Evidence in meteorites of former life: The organic compounds in carbonaceous chondrites are similar to those found marine sediments. *Annals of the New York Academy of Sciences*, **108**, 553-579.

Nininger, H. H. 1956. *Arizona's Meteorite Crater*. American Meteorite Lab, Denver, Colorado. 232 pp.

Nininger, H. H. 1971. The Published Papers of Harvey Harlow Nininger. (George A. Boyd, ed.) Publication No. 9 by the Center for Meteorite Studies, Arizona State University, Tempe AZ. (778 pages)

Nininger, H. H. 1972. Find a Falling Star. Paul S. Eriksson, Inc., New York. 254 pp.
Norton, O. R. 1998. *Rocks from Space*. 2nd ed. Mountain Press. Missoula, Montana, USA. 444 pp.

NYAS. 1963. Life-like Forms in Meteorites and the Problems of Environmental Control on the Morphology of Fossil and Recent Protobionta. *Annals of the New York Academy of Sciences*, **108**, 339-616.

Osborn, H. F. 1911. *The American Museum of Natural History: Its Origin, Its History, the Growth of its Departments, to December 31, 1909*. 2nd edition. The Irving Press, New York.

Peary, R. E. 1898. *Northward Over the "Great Ice", A Narrative of Life and Work along the Shores and upon the Interior Ice-Cap of northern Greenland in the Years 1886 and 1891-1897*. Frederick A. Stokes Co., New York. In two volumes. All page citations here are volume II.

Peters, J. J., & Pearson, C. L. Jr. 1988. The S.C.H. Bailey mineral collection of the American Museum of Natural History. *Matrix*, **1**, 3-6.

Peters, J. J., & Pearson, C. L. 1990. Clarence S. Bement: The consummate collector. *The Mineralogical Record*, **21**, 47-62.

Preston, D. J. 1986. *Dinosaurs in the Attic*. St. Martin's Press, New York. 244pp.

Prinz, M., Waggoner, D. G, & Hamilton, P. J. 1980. Winonaites: A primitive achondritic group related to silicate inclusions in IAB irons. *Lunar and Planetary Science*, **XI**, 902-904.

Prior, G. T. 1920. The classification of meteorites. *Mineralogical Magazine*, **90**, 51-63.

Prior, G. T. 1923. *Catalogue of Meteorites in the British Museum*. Printed by order of the Trustees of the British Museum, London.

Ramdohr, P. 1973. *The Opaque Minerals in Stony Meteorites*, Elsevier, Amsterdam. 245pp.

Reeds, C. A. 1937. Catalogue of the meteorites in the American Museum of Natural History, as of October 1, 1935. *Bulletin of the American Museum of Natural History*, **73**, 517-672.

Ross, J. 1819. *A Voyage of Discovery....Exploring Baffin's Bay and ....a North-West Passage*. London, John Murray. 252 + cxliv pages. (as cited in Buchwald 1975).

Shelby Cty. www. 2005. Sidney man touches the last frontier. http://www.shelbycountyhistory.org/schs/archives/people/clydefishpeoa.htm

SI-www. 2005. Smithsonian Institution Archives: Charles Upham Shepard Papers, with introduction and historical note. http://siarchives.si.edu/findingaids/FARU7283.htm (accessed June 6, 2005).

University of Rochester. 2005. A.W23 HENRY AUGUSTUS WARD PAPERS, web site 29-Jan-05. (http://www.lib.rochester.edu/rbk/HAWARD.stm)

Urey, H. C. 1961. Criticism of Dr. B. Mason's paper on 'The Origin of Meteorites'. *Journal of Geophysical Research*, **66**, 1988-1991.

Ward, H. A. 1901. *The Ward-Coonley collection of meteorites*. Chicago, iv+100pp, 6 plates. 28 pp. (privately published)

Ward, H. A. 1904a.Great meteorite collections: Some words as to their composition as affecting their relative values. *Proceedings of the Rochester Academy of Science*, **4**, 149-164.

Ward, H. A. 1904b The Willamette Meteorite. *Proceedings of the Rochester Academy of Science*, **4**, 137-148.

Ward, H. A. 1904c. Catalogue of the Ward-Coonley collection of meteorites. Chicago, 113 p + xii + illus. Marsh, Aitken & Curtis Co.

Ward, R. 1948. *Henry A. Ward, Museum Builder to America*. Rochester Historical Society Publications, vol 24. (book) 297 + xxiv pages

Warren, P. H. & Kallemeyn, G. W. 1989. Elephant moraine 87521: The first lunar meteorite composed of predominantly mare material. *Geochimica et Cosmochimica Acta*, **53**, 3323-3330.

Watters, T. R. & Prinz, M. 1979. Aubrites: Their origin and relationship to enstatite chondrites. *Proceedings of the 10th Lunar and Planetary Science Conference*, 1073-1093.

Weisberg M. K., Prinz M., Clayton R. N., Mayeda T.K., Grady M.M., Franchi I., Pillinger C.T. 1995. The CR chondrite clan. *Proc. NIPR Symposium on Antarctic Meteorites*, **8**, 11-32.

Whitfield, J. E. 1887. On the Johnson County, Arkansas, and Allen County, Kentucky, Meteorites (Cabin Creek and Scottsville). *American Journal of Science*, **33**, 500-501.

Whitfield, J. E. 1889. A new meteorite from Mexico (Bella Roca). *American Journal of Science*, **37**, 439-440.

Wiik, H. B. 1956. The chemical composition of some stony meteorites. *Geochimica et Cosmochimica Acta*, **9**, 279-289.

Wlotzka, F. 1994. Meteoritical Bulletin # 75. *Meteoritics*, **28**, 692.

Zolensky, M. E. 1998. The flux of meteorites to Antarctica. *In*: Grady, M. M., Hutchison, R., McCall, G. J. H. & Rothery, D. A. (eds) *Meteorites: Flux with Time and Impact Effects.* Geological Society, London, Special Publications, **140**, 93-104.

Figure Captions

Figure 1: Floors of the first building of the Museum. The minerals and meteorites were included in the fourth floor, as part of Geology (fossils). (reproduced from AMNH Annual Report, 1880)

Fig. 2: South Facade of AMNH, parallel to 77th street, 1907. Ground floor opening in lower left (SW) tower is where Ahnighito was moved into the new Ross Hall of Meteorites in 1980. The main entrance until 1936 is in the middle of the block. (AMNH Archive negative #32123s).

Figure 3. Etched 842 gram slab of the Hammond (Wisconsin) meteorite presented by the Swiss dealer H. Hoseus to C. S. Bement in 1874. (AMNH #125).

Figure 4: Morris Ketchum Jesup, with his dog Bruce (Brown, 1910).

Figure 5. Moving 'the Tent' across rails onto the *Hope*, 1897. (AMNH Archive negative #2A3974s)

Figure 6: Willamette meteorite in the Rose Center, side view c. 2001. (AMNH Archival Photo)

Figure 7: Decadal growth of the AMNH meteorite collection. First bar is the number of individual falls and finds represented in 1900, broken into meteorite categories (ordinary, carbonaceous, and enstatite chondrites, etc.; Pallasites, silicated irons, mesosiderites and some others are combined). Bars are cumulative new individuals added in each decade (e.g., 1951-1960 is '60'). The final bar shows the totals for the collection in 2005, all categories divided by three.

Figure 8: Photograph and caption from Gratacap's (1906) florid description of the Ward-Coonley Collection of meteorites. This is a fine example of typical displays in this era. The Hall is now the fourth floor Hall of Vertebrate Origins. (AMNH Archive negative #311211s)

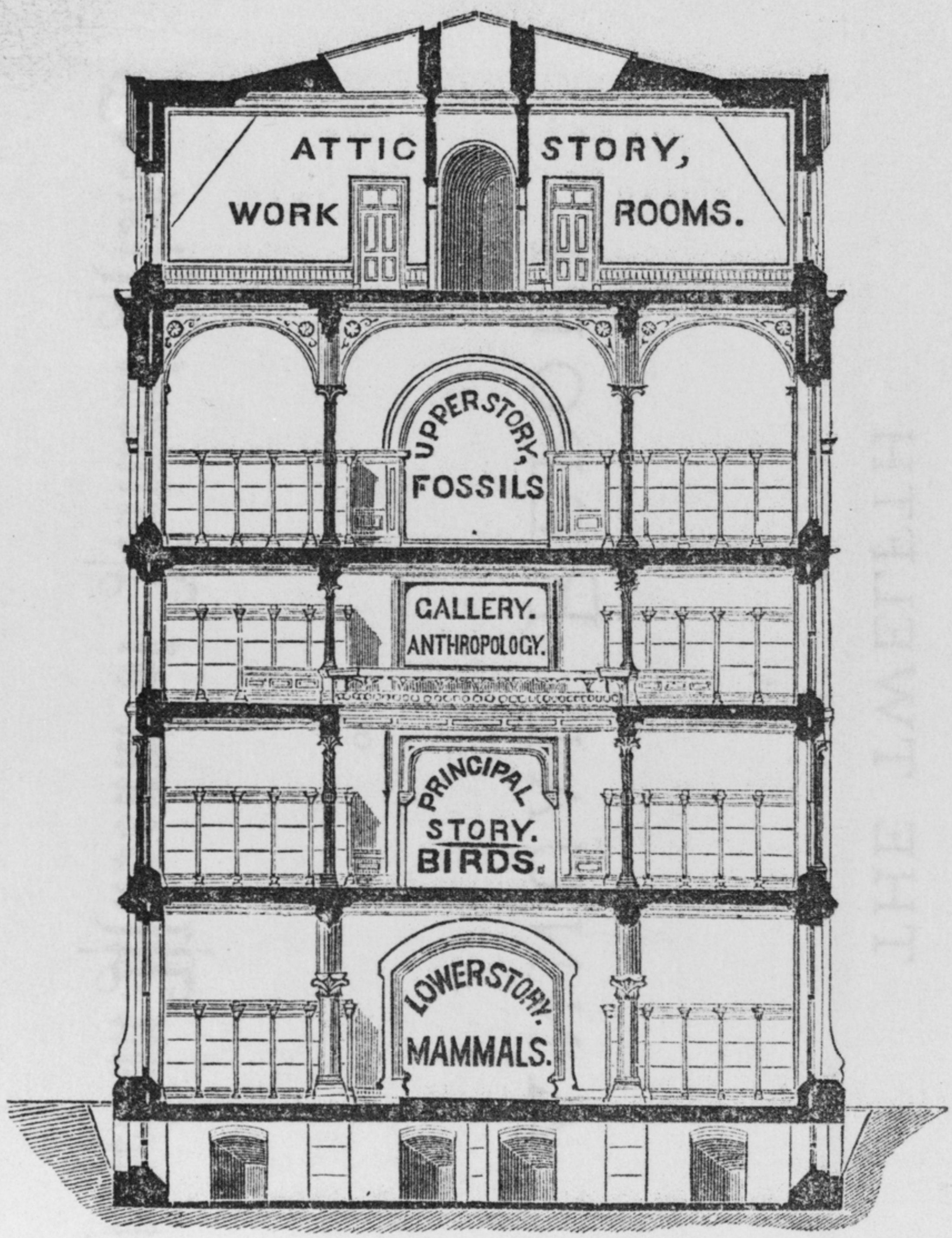
Figure 9: Map of the Hayden Planetarium main floor c. 1935, showing locations of meteorite specimens and cases. (Reeds 1937)

Figure 10: The Arthur Ross Hall of Meteorites as it opened in 1981. Ahnighito is central, with Gibeon and a Canyon Diablo iron in the foreground. (AMNH 1981)

Figure 11. Participants in the 1981 Ross Symposium on Meteoritics, in the Portrait Room at AMNH. Front row from left: Noel W. Hinners (Smithsonian National Air & Space Museum), Eugene M. Schoemaker (U.S. Geological Survey), Clark Chapmen (Planetary Science Institute, Tucson), Gerald J. Wasserburg (California Institute of Technology). Standing from left: John A. Wood (Harvard-Smithsonian Center for Astrophysics), Ronald Greeley (Arizona State U.), Donald E. Brownlee (U. Washington), Martin Prinz (AMNH), and Lawrence Grossman (U. Chicago). (AMNH 1981)

Selected meteorites listed in text:

page	Name (find/fall, place, year, type, AMNH spec#)
	*specimen numbers are lowest # of all extant numbers for each meteorite.
p. 4	Searsmont (fall, Waldo County Maine, 1971, H5, #370)
p.13	Selma (find, Alabama, 1906, H4, #2223)
p.13	Russel Gulch (find, Colorado, 1863, IIIA, med. oct., #34)
p.13	Ness County (find, Kansas, 1894, L6, #612)
p.13	Modoc (fall, Kansas, 1905, L6, #630)
p.13,17	Brenham (find, Kansas, 1882, PAL, #56)
p.13	Tamarugal (find, Tarapaca, Chile, 1904, IIIA med oct, #2461)
p.13	Gibeon (find, Namibia, 1836, IVA fine oct, #777)
p.13	Knowles (find, Oklahoma, 1903, IIIA med. oct., #208)
p.13,17	Willamette (find, Oregon, 1902, IIIAB med. oct., #203)
p.13	Guffey (find, Colorado, 1907, UNGR ataxite, #213)
p.13,37	Johnstown (fall, Colorado, 1924, DIO, #2493)
p.13	Holbrook (fall, Arizona, 1912, L6, #586)
p.13	Tomhannock Creek (find, New York, 1863, H5, #1034)
p.13	Cruz del Aire (find, Nuevo Leon, Mexico, 1911, UNGR fine oct., #279)
p.16	Jajh deh Kot Lalu (fall, Sind, Pakistan, 1926, EL6, #3954)
p.16	Dalgety Downs (find, Western Australia, 1941, L4, #4188)
p.16	Wolf Creek (find, Western Australia, 1947, IIIAB med. oct., #3844)
p.19	Cape York (find, West Greenland, 1818, IIIAB med. oct., #867)
p.19	Cañon Diablo (find, Coconino County, Arizona, 1891, IAB coarse oct., #9)
p.19	Forest City (fall, Winnebago County, Iowa, 1890, H5, #361)
p.19	Long Island (find, Phillips County, Kansas, 1891, L6, #367)
p.19	Tucson (find, Pima County, Arizona, 1850, ataxite, #221)
p.23	Kyushu (fall, Kyushu, Japan, L6, #493)
p.24	Esquel (find, Argentina, 1951, PAL, #4050)
p.24	Estacado (find, Oklahoma, 1903, 161 kg., H6, #587)
p.28	Chassigny (fall, France, 1815, SNC, #434)
p.28	Serra de Magé (fall, Brazil, 1923, EUC, #3786)
p.28	Chervony Kut (fall, Ukraine, 1937, EUC, #4473)
p.28	Emery (find, S. Dakota, 1962, MES, #4367)
p.28	Lodran (fall, Pakistan, 1868, LOD, #314)
Fig. 3	Hammond (find, Wisconsin, 1884, UNGR med. oct., #125)



TRANSVERSE SECTION.

Fig. 1

Fig. 2

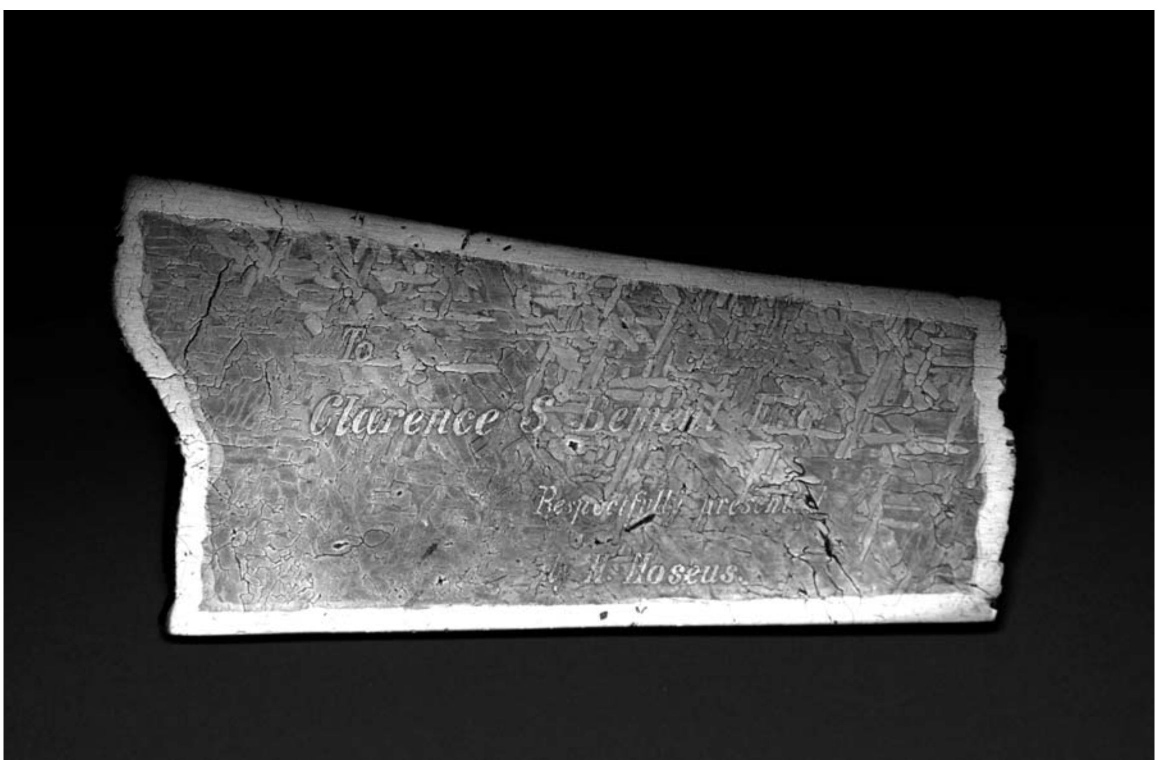


Fig. 3

Mr. Jesup and his Collie Bruce.

Fig. 4


Fig. 5

Fig. 6

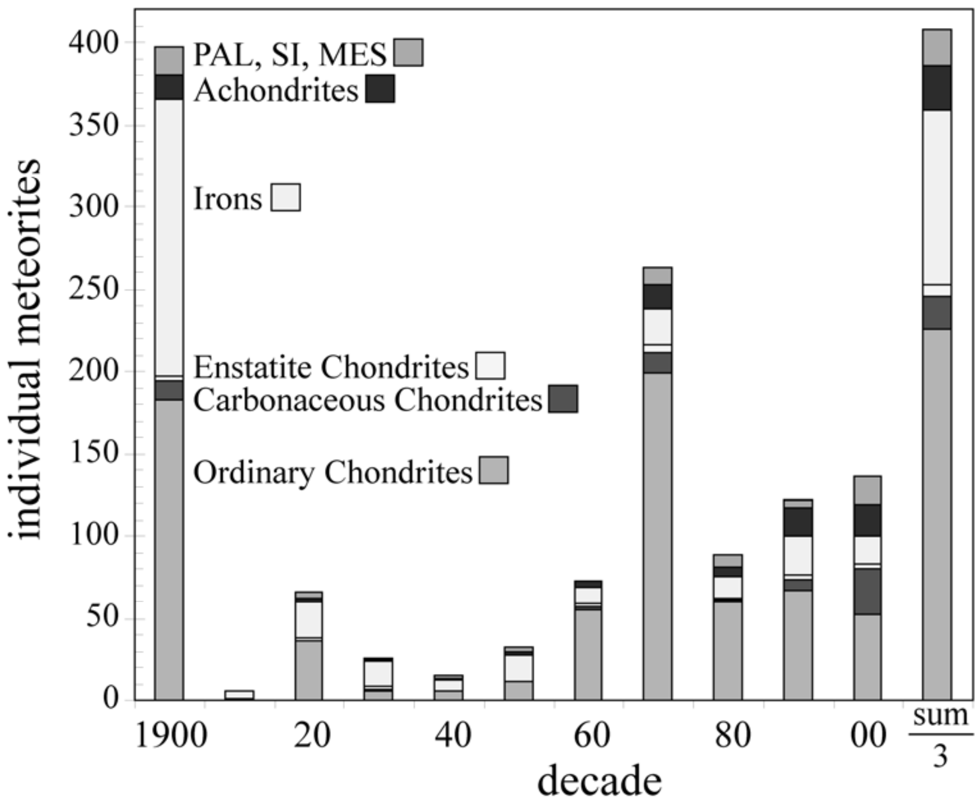

PAL, SI, MES
Achondrites
Irons
Enstatite Chondrites
Carbonaceous Chondrites
Ordinary Chondrites
individual meteorites
0
50
100
150
200
250
300
350
400
1900
20
40
60
80
00
sum
3
decade

Fig. 7

Fig. 8

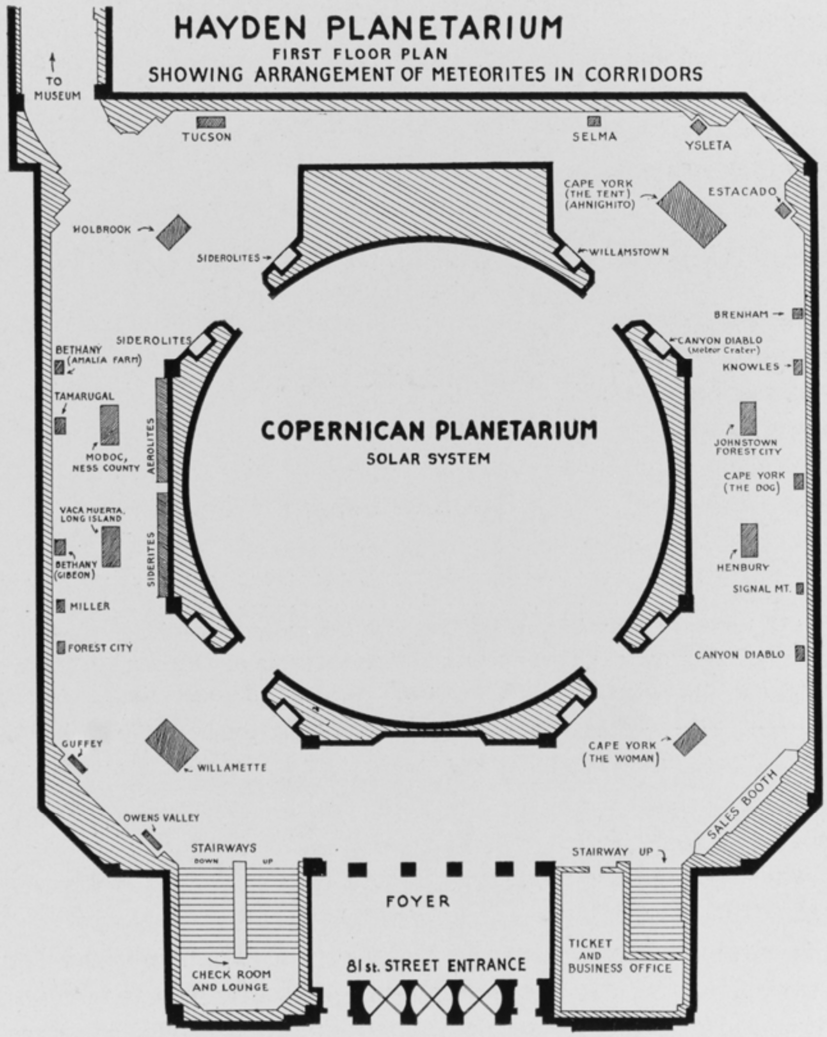

HAYDEN PLANETARIUM
FIRST FLOOR PLAN
SHOWING ARRANGEMENT OF METEORITES IN CORRIDORS
TO MUSEUM
TUCSON
SELMA
YSLETA
CAPE YORK (THE TENT) (AHNIGHITO)
ESTACADO
HOLBROOK
SIDEROLITES
WILLAMSTOWN
BRENHAM
SIDEROLITES
CANYON DIABLO (Meteor Crater)
BETHANY (AMALIA FARM)
KNOWLES
TAMARUGAL
MODOC, NESS COUNTY
AEROLITES
COPERNICAN PLANETARIUM
SOLAR SYSTEM
JOHNSTOWN FOREST CITY
CAPE YORK (THE DOG)
VACA MUERTA, LONG ISLAND
SIDERITES
BETHANY (GIBEON)
HENBURY
SIGNAL MT.
MILLER
FOREST CITY
CANYON DIABLO
GUFFEY
WILLAMETTE
CAPE YORK (THE WOMAN)
SALES BOOTH
OWENS VALLEY
STAIRWAYS
DOWN
UP
STAIRWAY UP
FOYER
TICKET AND BUSINESS OFFICE
81st. STREET ENTRANCE
CHECK ROOM AND LOUNGE

Fig. 1.

Fig. 9

Fig. 10

Fig. 11