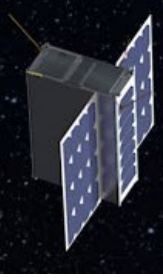
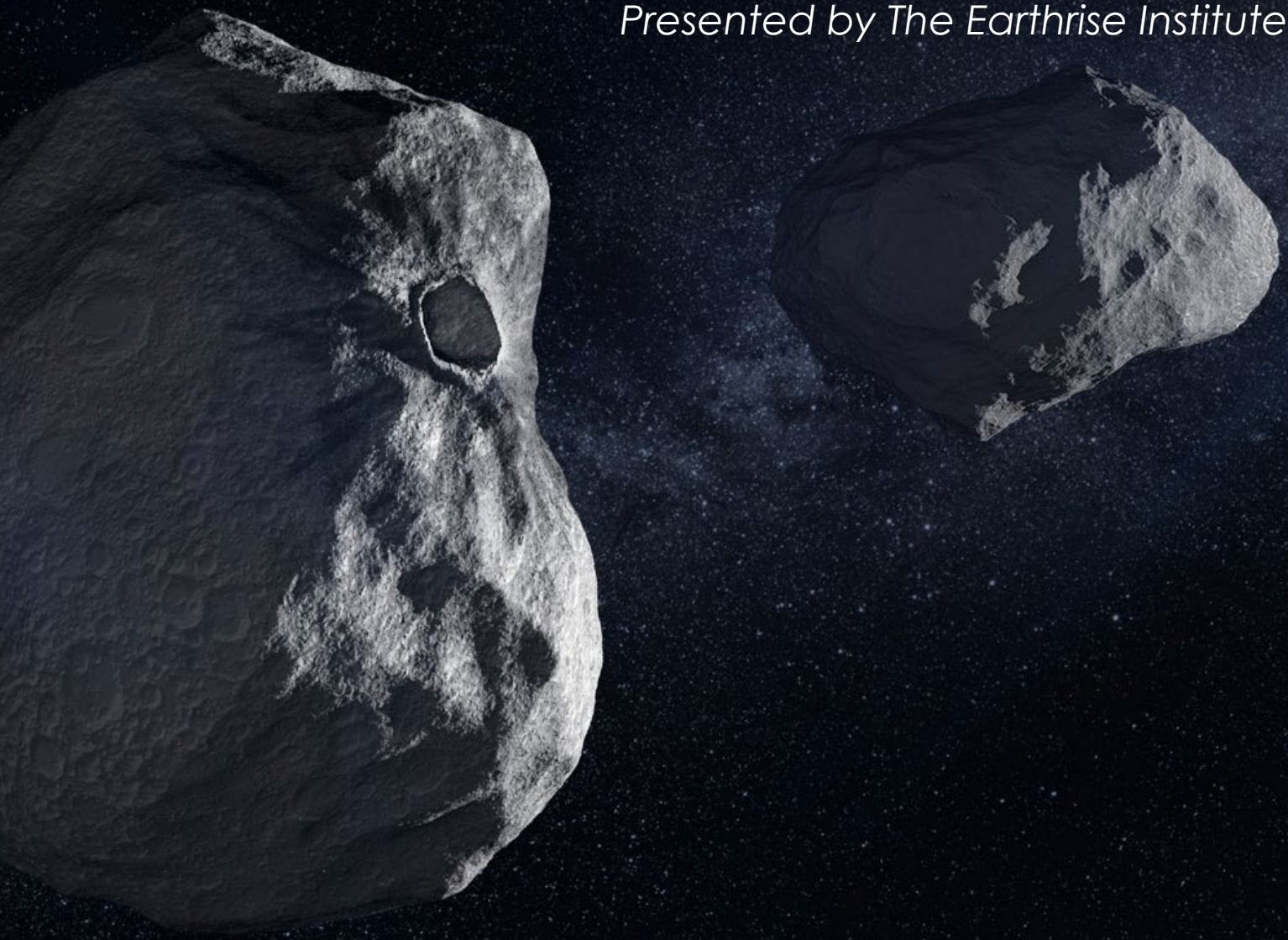


ICE & STONE 2020

WEEK 22: MAY 24-30

Presented by The Earthrise Institute



#22

Authored by Alan Hale

THIS WEEK IN HISTORY

MAY **24** 25 26 27 28 29 30

MAY 24, 1981: American astronomer Harold Reitsema and his colleagues, observing from Arizona, detect a possible moon of Neptune during an apparent occultation of a background star. This object was confirmed by Voyager 2 during its flyby of Neptune in August 1989 and is now known as Larissa and designated as Neptune VII.

Two views of Larissa, a dark, irregularly shaped moon of Neptune discovered in 1989 by Voyager 2. Courtesy of NASA/JPL.

MAY 24, 2001: Comet LINEAR C/2001 A2, the first relatively bright naked-eye comet of the 21st Century, passes through perihelion at a heliocentric distance of 0.779 AU. It is a future "Comet of the Week."

24 MAY **25** 26 27 28 29 30

MAY 25, 44 B.C.: According to approximate orbital calculations, the comet known as "Caesar's Comet" (formally designated C/-43 K1) passes through perihelion at a heliocentric distance of 0.22 AU. It is this week's "Comet of the Week."

COVER IMAGE CREDIT:

Front and back cover: This artist's conception shows ESA's proposed Hera Mission to the Didymos binary asteroid system. Hera will carry two CubeSat Opportunity Payloads (COPINS) to support the science goals of the main spacecraft, as well demonstrate deep space inter-satellite link techniques. Courtesy of ESA/ScienceOffice.org.

24 25 26 MAY 27 28 29 30

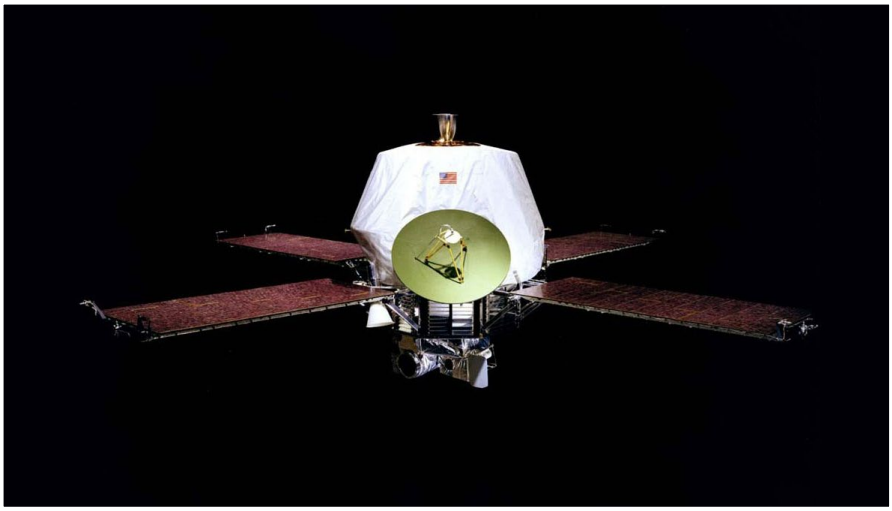
MAY 27, 1894: Arctic explorer Robert Peary, together with Hugh Lee and an Inuit guide named Tallakoteah, locate what is now known as the Cape York meteorite on an island off the northwestern coast of Greenland. This meteorite is now on display at the American Museum of Natural History in New York, and it along with other large meteorites that have been found on Earth's surface constitute the subject of this week's "Special Topics" presentation.

MAY 27, 2020: Comet SWAN C/2020 F8 will pass through perihelion at a heliocentric distance of 0.430 AU. This comet, which was discussed in a previous "Comet of the Week" presentation, was dimly visible to the unaided eye from the southern hemisphere late last month and early this month, and presently is detectable from the northern hemisphere albeit at a small elongation from the sun. Current information about it can be found at the Comet Resource Center.

24 25 26 27 28 29 MAY 30

MAY 30, 1971: NASA's Mariner 9 mission is launched from Cape Canaveral, Florida, towards Mars. Mariner 9 became the first spacecraft to orbit Mars, and in addition to discovering numerous important features on Mars' surface also returned the first clear images of Mars' moons Phobos and Deimos.

***THERE ARE NO EVENTS LISTED FOR THE DATES OF MAY 26, 28 AND 29.**



Above: Mariner 9 was the first probe to enter orbit around another planet. Courtesy of NASA/JPL.

Right: The interplanetary spacecraft was launched onboard an Atlas-Centaur rocket on May 31, 1971. Courtesy of the US Air Force.

COMET OF THE WEEK: "CAESAR'S COMET" C/-43 K1

Perihelion: 44 B.C. May 25.00, q = 0.22 AU

Roman coin minted by Caesar Augustus circa 18-19 B.C. The "tails" side shows an eight-rayed comet with the tail directed upward. The Latin inscription reads "Divine Julius." Courtesy Classical Numismatic Group, licensed via Creative Commons.

The appearance of a bright comet is certainly a stimulus of important scientific investigations, and, under the right circumstances, in today's society can also be a focus for popular culture, at least for a while. In more ancient times, however, when comets were still widely considered to be a supernatural or mystical phenomenon, they sometimes ended up playing a role in the shaping of human history. Perhaps the most dramatic example of this is the bright comet that appeared during 44 B.C.

The biggest world event that year was the assassination of the Roman ruler Julius Caesar by several members of the Roman Senate on March 15 (the "Ides of March"). Caesar, who among other things was responsible for the development of the Julian calendar that governed affairs of much of the world for the next millennium and a half, had conquered and unified much of that part of the world into the Roman Republic. His assassination threw Rome into turmoil and led to several civil wars, but after several years his grandnephew and appointed heir Octavian successfully re-established order and took control as the first Emperor of the Roman Empire under the name Caesar Augustus.

Chinese and Korean astronomers reported the appearance of a bright comet during May of that year. The earliest reports date from May 18, and indicate that the comet was in the western sky, with a tail 8 to 10 degrees long. It traveled northward, and at perihelion on May 25 would have been only 11 degrees from the sun, and thus would have had to have been as bright as magnitude -2 or -3 to have been readily detected with the unaided eye; Chinese records indicate a tail 10 to 15 degrees long pointing towards the northeast. It went through conjunction north of the sun a few days later and emerged into the morning sky, and according to the Chinese records was last seen on June 16.

According to several Roman writers, a brilliant comet – bright enough to see during daytime – appeared for seven days near the beginning of the Ludi Victoriae Caesaris festival held in honor of Julius Caesar, and was widely believed by the Roman public to be the soul of Julius Caesar ascending into heaven. Octavian shrewdly seized upon this and utilized it to advocate for a deification of Julius Caesar and at the same time push his own political agenda, an effort that ultimately succeeded.

This deification of Julius Caesar is described by, among others, the Roman poet/historian Ovid in Book

The assassination of Julius Caesar, painted by William Holmes Sullivan, c. 1888. Courtesy of Creative Commons.

XV of his Metamorphoses, where he has Jupiter saying to Venus (lines 839-849):

"'Meanwhile take up Caesar's spirit from his murdered corpse, and change it into a star, so that the deified Julius may always look down from his high temple on our Capitol and forum.'"

"He had barely finished, when gentle Venus stood in the midst of the senate, seen by no one, and took up the newly freed spirit of her Caesar from his body, and preventing it from vanishing into the air, carried it towards the glorious stars. As she carried it, she felt it glow and take fire, and loosed it from her breast: it climbed higher than the moon, and drawing behind it a fiery tail, shone as a star."

Somewhat more recently, William Shakespeare, in his play Julius Caesar, has Caesar's wife Calpurnia say to him on the fateful morning of March 15 (Act II, Scene 2):

"When beggars die there are no comets seen;
The heavens themselves blaze forth the death of princes."

Astronomers have had a difficult time reconciling the Chinese reports in May with the later Roman reports, and for a time there was thought that the reports might be referring to two separate comets. Some scholars had originally dated the Ludi Victoriae Caesaris as having occurred in September, but more recent dating places them in late July. This earlier dating does help in reconciling the reports, as it allows the positional data (such as it is) to be fit by a reasonably valid orbit, but there is the obvious difficulty that, for the reports to be believed, a comet two months past perihelion passage would have had to have suddenly burst into daylight-visible brightness. The most widely accepted explanation is that the comet had faded more-or-less normally as it receded from perihelion, but then underwent a major outburst of several magnitudes in late July, most fortuitously near the beginning of the Roman festival.

Several historical and astronomical scholars have researched this, and although this remains the generally-accepted explanation, there remains some skepticism about the Roman reports, with some scholars even venturing the idea that the comet's "appearance" during the Roman festival was nothing more than an after-the-fact propaganda ploy developed by Octavian and/or his associates. (For whatever it's worth, the comet – at least according to the uncertain given orbit – never came close to Earth, with minimum geocentric distances of 0.96 AU in mid-May and just under 1.0 AU near the beginning of August.) Whatever might have really happened would seem to be lost within the mists of time.

SPECIAL TOPIC: LARGE GROUND METEORITES

The Hoba meteorite in Namibia. Image courtesy Sergio Conti, licensed via Creative Commons.

The general topic of meteorites was discussed as a "Special Topics" presentation four weeks ago. The large majority of meteorites that are known are not especially large, being of the order of a few kg in mass; with only a handful of exceptions, even the larger ones tend to have a mass of no more than a few tens of kg. Meteorites that are much larger than this tend to be quite rare, and not too many of these are known.

The discussion of what constitutes the "largest" meteorites is somewhat a matter of definition. Many incoming meteors tend to fragment as the pass through the atmosphere, and whatever fragments – or complete meteorites, for that matter – that hit the ground might subsequently be broken apart, sometimes by humans or perhaps by weathering or other causes. The "largest" meteorites can therefore mean the largest individual fragments, or it can mean the largest combined mass of all the various fragments. For the purposes here, I will generally use "largest" to mean the largest individual fragments, although at times I might consider it appropriate to include the combined fragments as part of the overall discussion.

With only a few exceptions, almost all of the largest known meteorites are of the iron-nickel type. Even though these are relatively rare compared to stony meteorites, they are significantly denser, i.e., more massive per volume, than similarly-sized stony meteorites, and are also much more likely to survive their passage through the atmosphere without disintegrating. The largest known stony-iron meteorites are two fragments of the Brenham meteorite found near Haviland, Kansas (and which are possibly associated with an impact crater near there); these have masses of 650 kg and 450 kg. The largest stony

meteorite known is apparently a 654-kg fragment of the Chelyabinsk meteorite that fell near Chelyabinsk, Russia on February 15, 2013 (and which is discussed as part of a future "Special Topics" presentation).

Almost all of the largest iron meteorites are the results of falls that took place thousands of years ago. (The largest iron meteorite resulting from an observed fall is apparently a 1745-kg fragment of the Sikhote-Alin meteorite that fell in Siberia on February 12, 1947; this is discussed, along with the Chelyabinsk meteor and other recent Earth "impacts," in a future "Special Topics" presentation.) Many of these meteorites have been known, and sometimes venerated, by indigenous peoples for many centuries, and have been "discovered" and identified as meteorites, and scientifically analyzed as such, only within the relatively recent past.

The largest known meteorite in the world is the Hoba meteorite (sometimes referred to as the "Hoba West" meteorite) that was found near the town of Grootfontein in what is now Namibia. It was discovered in 1920 by the owner of the land, Jacobus Brits, a farmer, who was plowing one of his fields with an ox when the plow struck something solid and stuck. When the obstructing rock was excavated it was found to be an iron meteorite roughly 3 meters by 3 meters by 1 meter in size, with a mass initially estimated to be 66 tons, although weathering and sample removal have now decreased the mass to about 60 tons.

Chinese researchers measuring the recently discovered Akebulake meteorite in China. Image courtesy Xinhua.

Analysis indicates that the Hoba meteorite fell to Earth approximately 80,000 years ago. There are no impact craters or other known features associated with it, possibly due to a relatively slow impact velocity and/or to skipping along the ground after impact. Due to its large size it has never been moved from its discovery site; the ground around it has been dug out and the Namibian government has designated the site as a National Monument.

Robert Peary with the Ahnighito fragment, the largest fragment of the Cape York meteorite, on site in Greenland. From Peary's memoir "Northward Over the Great Ice."

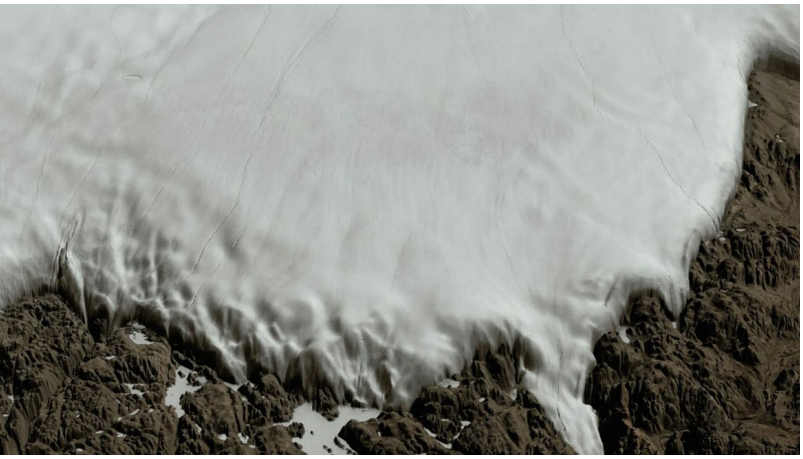
Another large meteorite in Africa is Mbozi, near the city of Mbeya, Tanzania. Indigenous peoples called it "kimondo," and it was later "discovered" by scientists in 1930. It has a mass of 16 tons and, like Hoba, there is no nearby impact crater; it, too, may have rolled along the surface after impact.

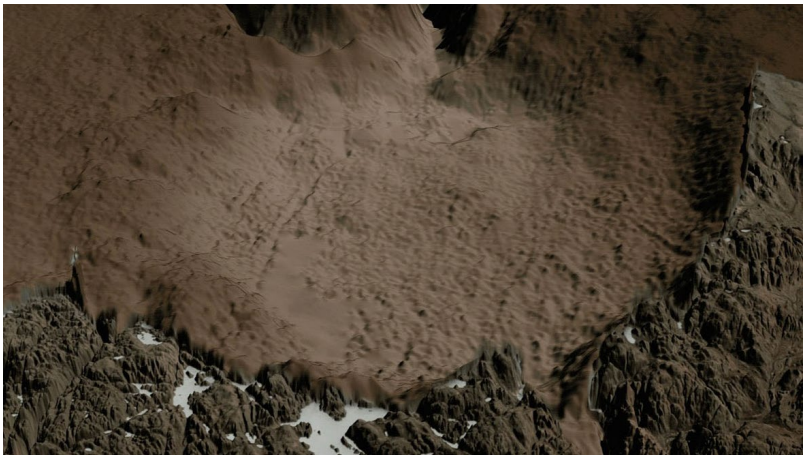
One of the other large single meteorites is the Bacubirito meteorite, discovered in 1863 by geologist Gilbert Bailey near the village of Ranchito in the Mexican State of Sinaloa. It is roughly 4 meters long by 2 meters wide, with an approximate mass of 22 tons, and is presently located at the Centro de Ciencias de Sinaloa.

Certainly one of the largest multiple-fragment meteorites is the Campo del Cielo ("Field of Heaven") set of meteorites located near the border of the provinces of Chaco and Santiago del Estero in northern Argentina. Indigenous peoples in the area had known of these rocks for centuries, even constructing weapons out of them, and it was examined by an expedition commissioned by the provincial Governor in 1576. The meteorites cover a strewnfield 18 km long by 3 km wide that contains numerous impact craters, attesting to the original meteorite fall that took place approximately 4500 years ago and that is described in the indigenous peoples' legends.

Many fragments of the Campo del Cielo field have been recovered, most within the fairly recent past. The El Chaco fragment, located in 1969 and extracted in 1980, has a mass of 29 tons, and meanwhile, the largest fragment, Gancedo – discovered underground by the Asociacion de Astronomia del Chaco as recently as September 10, 2016 and later unearthed – has a mass of 31 kg, making it the third-largest meteorite fragment identified on Earth to date.

Another significant collection of meteorite fragments is the set of Aletai meteorites that have been found





The Hiawatha crater in northwestern Greenland. Left: Photograph of the Greenland Ice Sheet. Right: Topography of the rock underneath the ice sheet, showing the outline of the crater. Images courtesy NASA.

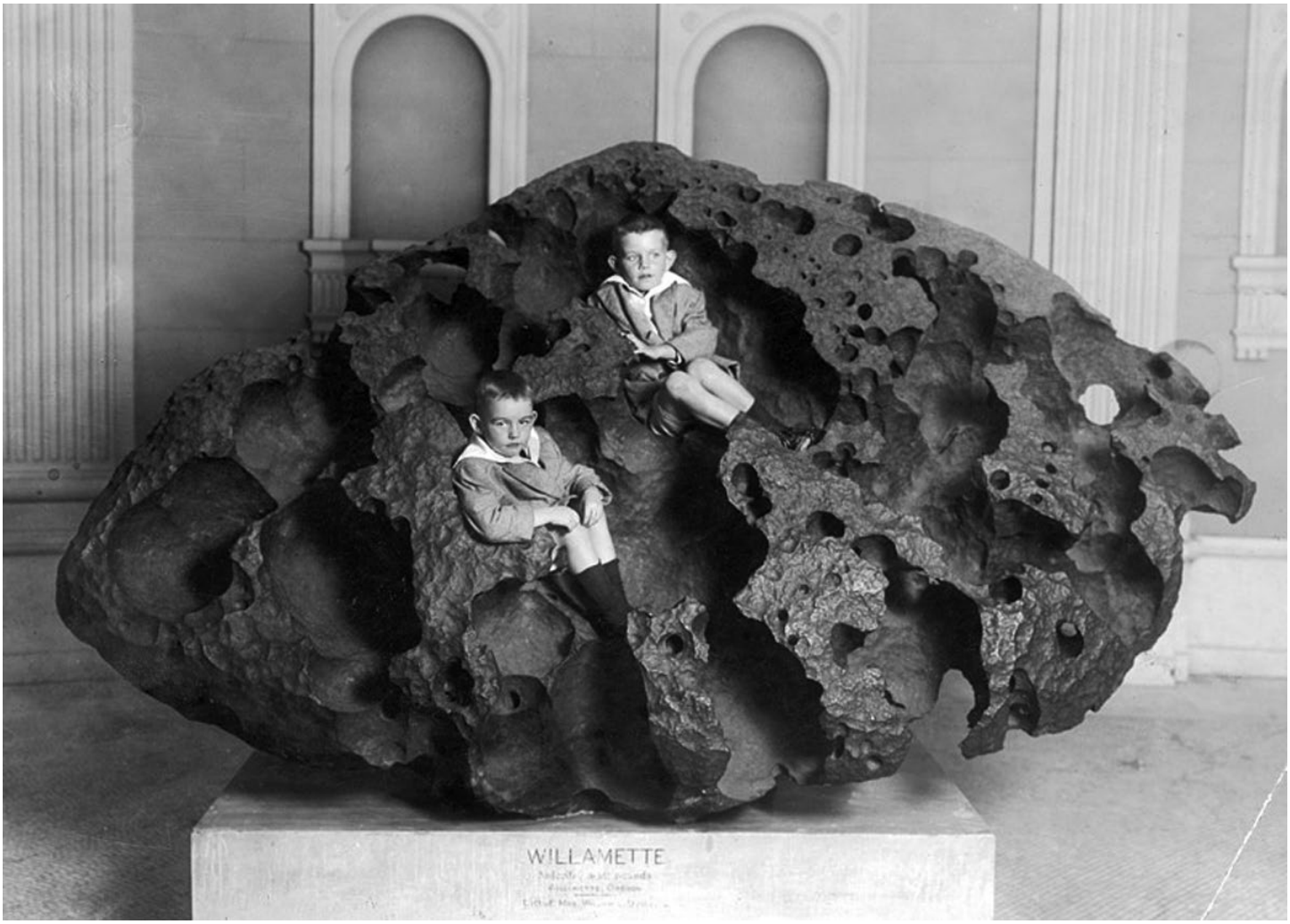
in the Xinjiang Ulyghur Autonomous Region in northwestern China. The largest fragment, Armanty, with a mass of 28 tons, was "discovered" in 1898, and another large fragment, Akebulake, with a mass of 18 tons, was "discovered" as recently as 2011. Both fragments carry "graffiti" in the form of signatures inscribed upon them apparently by passing herdsmen.

One of the most famous large ground meteorites is the Cape York meteorite, in actuality a group of several large fragments near Cape York in far northwestern Greenland. The Inuit population who lived near there were well aware of the meteorites and utilized the iron within them to build tools and harpoons. In 1818 a British Naval officer, John Ross, was leading an expedition for the fabled "northwest passage" and encountered several members of the Inuit population, and upon examining their metal tools correctly concluded that they came from an iron meteorite, however the local people would not reveal the location of their source of iron.

Several expeditions over the next few decades tried to find this meteorite, but failed. Finally, in 1894 American Naval officer and famed Arctic explorer Robert Peary led another expedition and gained the trust of the Inuit population, and on May 27, together with fellow expedition member Hugh Lee and an Inuit guide name Tallakoteah, located the fabled "Iron Mountain" and at least three fragments on a small island called "Saviksoah" by the native population but now known as (for obvious reasons) "Meteorite Island." Over the next three years Peary successfully brought these three fragments to the U.S.; the largest, named Ahnighito by Peary, has a mass of 31 tons and is the second-largest meteorite found thus far on Earth; it is on display at the American Museum of Natural History in New York. A Danish scientist, Vagn Buchwald, discovered a fourth large fragment of the Cape York meteorite in 1963 on Greenland's Agpalilik peninsula (and thus is named "Agpalilik"); this fragment, with a mass of 20 kg, is on display at the Natural History Museum of the University of Copenhagen.

Analysis of the Cape York meteorite fragments indicates that it fell to Earth at least 10,000 years ago and quite possibly much earlier than that. In 2018 a large circular basin – quite possibly an impact crater – 31 km in diameter was detected approximately 1 km below the ice surface of the Hiawatha Glacier in northwestern Greenland. While it has not yet been possible to date the age of this "Hiawatha Crater" directly, indirect evidence suggests that it is likely between 12,000 and 50,000 years old – consistent with the possible fall date of the Cape York meteorite. (There is indeed indirect evidence that this putative crater was formed by the impact of an iron-rich asteroid.) There has even been speculation that the putative Hiawatha Crater – and, thus, the Cape York meteorite fall – might be associated with the Younger Dryas climate change era that took place approximately 12,000 years ago, but this idea is not widely accepted at this time.

A rather colorful story surrounds the Willamette meteorite, which with a mass of 14 tons is the largest meteorite found in the U.S. (in the Willamette River valley in northwestern Oregon). It had been long known and considered sacred by the indigenous Native American peoples of that region, and was then "discovered" in 1902 by a Welsh immigrant settler, Ellis Hughes. Realizing the significance of what he had found but also realizing that it was not on his property, Hughes, assisted by his teenage stepson, clandestinely worked to move the meteorite to his property, taking three months to do so. Upon completing this task he built a small shed around it and charged admission, but one of those who came to view it was the attorney for the property owners where Hughes had found the meteorite, the Oregon Iron and Steel Company. The company sued Hughes to get the meteorite back, and Hughes took the case all the way to the Oregon Supreme Court, who ruled against him with the argument:



Two boys inside depressions of the Willamette meteorite. The depressions were created by rainwater reacting with minerals inside the meteorite to form an acid that dissolved some of the meteoritic material. Courtesy American Museum of Natural History.

"A meteorite or aerolite, though not imbedded in the earth, is nevertheless real estate, belonging to the owner of the land, and not personal property, in the absence of proof of severance." (Oregon Iron Co. v. Hughes, 1905)

After retrieving the meteorite from Hughes' residence, the Oregon Iron and Steel Company took it to Portland where it was exhibited at the Lewis and Clark Centennial Exposition. Afterwards, it was donated to the American Museum of Natural History in New York, where it is currently displayed. During the final years of the 20th Century an organization of Native American tribes filed a lawsuit against the Museum demanding the meteorite's return, but reached an agreement with the Museum whereby once a year the tribal members are able to conduct a private ceremony around the meteorite, and that it would be returned back to their Native land if and when the Museum stops displaying it.

There is no impact crater anywhere near the site where the Willamette meteorite was found and researchers believe that it fell several thousand years ago, during the last Ice Age, in southern Canada or Montana. After landing on top of the ice cap that covered the area at that time, it was later carried southward by glaciers and then by icebergs swept along by the Missoula Floods 13,000 to 15,000 years ago. A variation of this theme, i.e., the fact that no one knew where the Willamette meteorite had initially fallen, was actually used by Hughes as part of his defense in the lawsuit against him, but to no avail.

The fact that some of the largest meteorites found on Earth have only been identified within the past decade, e.g., the Gancedo and Akebulake meteorite fragments, suggests the possibility that more such objects remain to be found. There are still many locations on Earth's surface – including, certainly, on the ocean floor, although weathering would likely play a significant factor there – that are accessible only with difficulty and that remain largely unexplored, and thus future intrepid explorers might yet be able to add to this description of large ground meteorites.

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