mini museum

"Man ska vara snäll."

"One should be kind."

– Dr. Jörgen Fex

mini museum:

a companion guide to the third edition.
billions of years of history as seen from planet earth.

HANS-FILIP J. FEX

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A private donation has also been made to the Wikimedia Foundation.

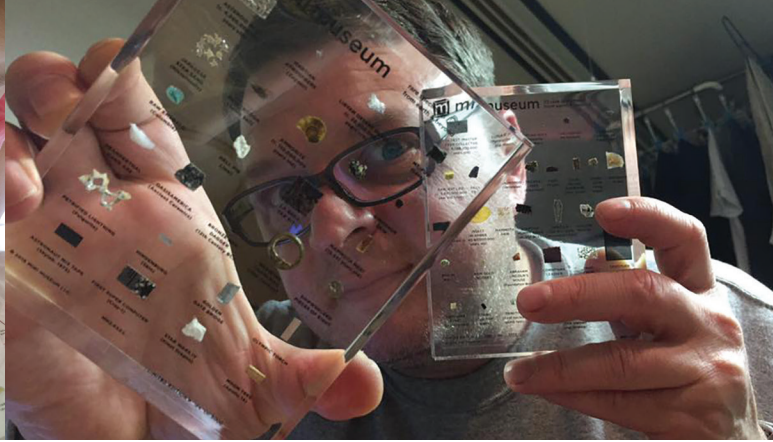
contents

hello, everyone!

Welcome to the Third Edition of the Mini Museum. My name is Hans Fex and I am the creator of the Mini Museum.

The Mini Museum is a personal collection of rare specimens from Earth and beyond. Each item in the Mini Museum is authentic, iconic, and labeled. The entire collection is encased in acrylic for display and will last for many years.

For the Third Edition, we've brought together billions of years of history, which is an incredible thing to think about. Consider all that has come before this moment in your own life. Now expand that to your parents and their parents before them. Go back as far as you can and consider the journey that brought you to this very moment. Now take a deep breath as we go even further.



You're about to take a journey

which begins with the birth of the solar system and space gems created in the heart of an asteroid, and ends with a meal prepared for humanity's first successful community in space. In between, you'll soar to new heights in the famous SR-71 Blackbird, witness cataclysmic events, and consider pivotal moments in human civilization. You'll hold three of the largest predators in history in the palm of your hand, and learn about other fascinating creatures from the deep past. You'll visit ancient cultures, famous places, and take a trip down the world's oldest river. You'll discover the earliest known remains of our planet, learn how the very breath you're taking right now has been billions of years in the making, and visit with some of the most famous people of all time.

I know that's a lot to take in all at once, because it's something I think about each time I look at the Mini Museum. I also think about all of the people who have helped make this journey possible.

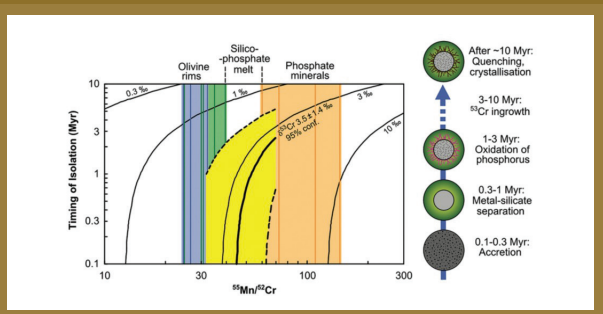
Since our first project nearly three years ago, we've shipped more than ten thousand Mini Museums all over the world. We've also met many fascinating collectors, scientists, and adventurers. We've learned so much at each step and I am so very grateful.

I truly hope you enjoy the Third Edition of the Mini Museum. The universe is amazing, and I am so happy to share this incredible collection with you.

Now, it's back to work!

Hans Fex

CREATOR AND
CHIEF CURATOR OF
THE MINI MUSEUM



The creation of pallasites is a topic of active debate among scientists. The leading theory focuses on the effect of lower gravity in small planetesimals and large asteroids on differentiating materials during the early formation of the solar system. A competing theory suggests peridot may have formed in the remains of the solar nebula.

SPECIMEN TYPE:
METEORITE & GEMSTONE

ESTIMATED AGE:
4,557,000,000 YEARS OLD

RARITY:
LESS THAN 1% OF ALL METEORITES ARE CLASSIFIED AS PALLASITES

space gems
(pallasite peridot)

"On the basis of a modest conjecture, I have undertaken a dangerous journey. Yet, already I see the foothills of new lands."

– Immanuel Kant, 1755 *Universal Natural History and Theory of the Heavens*

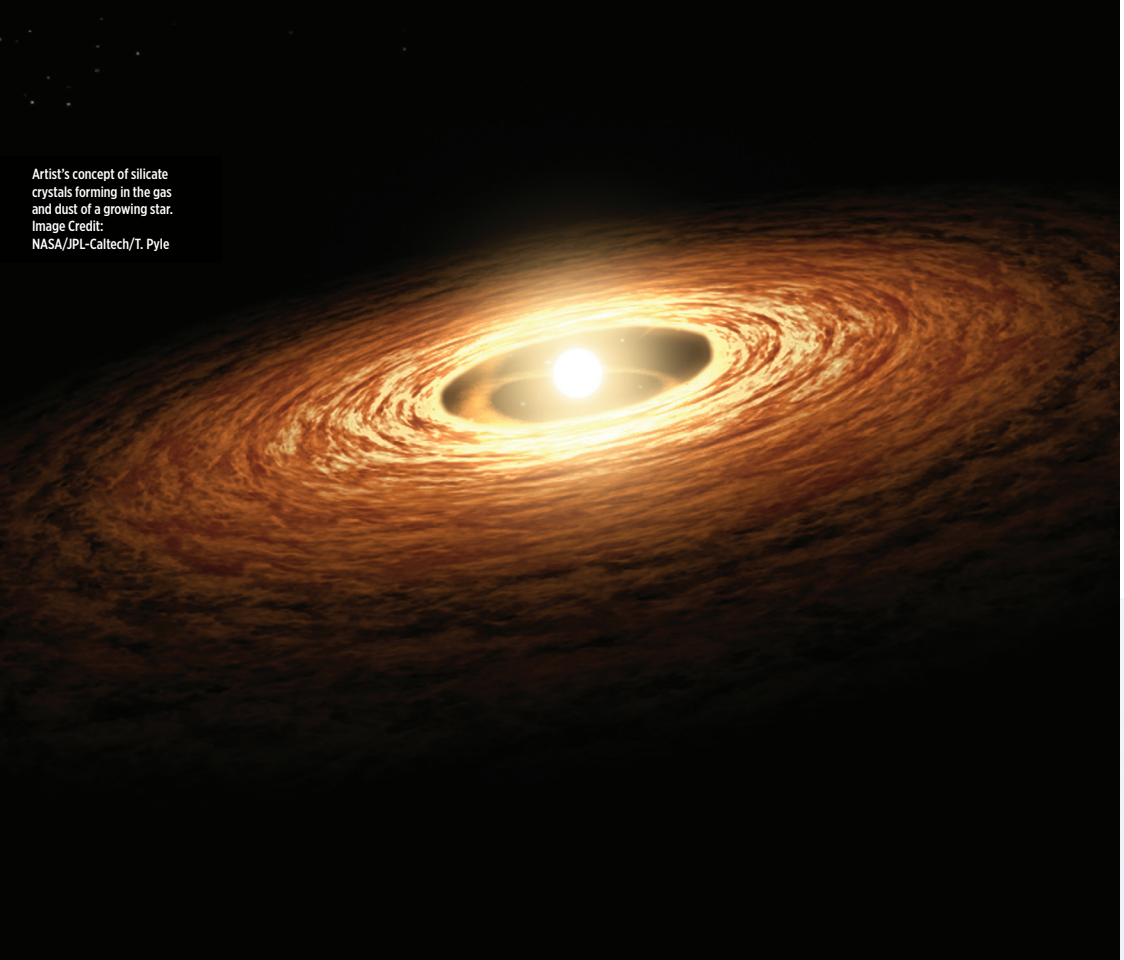
Created in the heart of an asteroid just after the birth of the solar system, Pallasite Peridot is among the rarest and oldest gems. Pallasites are characterized by a unique matrix of the mineral Olivine embedded in solidified iron and nickel. The combination of such materials is as surprising to science as it is beautiful to the eye.

Scientists often work backwards from existing materials and observations, unraveling their creation through experimentation. Studying the formation of pallasites provides insights into the earliest days of the solar system and clues to the formation of planetary systems in general.

The unusual matrix of the Pallasite is formed by the intrusion of molten metal into layers of Olivine. Olivine is made of magnesium iron silicate with numerous variations on Earth and beyond. We have discovered Olivine on the Moon and Mars and detected Olivine's spectral signature in the dust disks surrounding young stars and in comet tails. Peridot is the gem quality variant of Olivine.

While this sort of mixing is likely to occur in the reaction zones between the core-mantle boundary in large bodies, gravity should separate these materials due to their varied densities. This is one reason that pallasite formation is such an active topic in the scientific community; it also explains why less than 1% of all found meteorites are classified as pallasites.

The specimens in the Mini Museum are fragments of Peridot from the Jepara meteorite discovered in 2008 on the Indonesian island of Java. The original mass weighed 499.5 kg (1100 lbs) with a diameter of just 85 cm (33 in).



Artist's concept of silicate crystals forming in the gas and dust of a growing star. Image Credit: NASA/JPL-Caltech/T. Pyle

SOURCES:

McSween Jr, Harry Y., et al. "HED meteorites and

McKibbin, S. J., et al. "Rapid cooling of planetesimal core-mantle reaction zones from Mn-Cr isotopes in pallasites." Geochem. Perspect 2 (2016): 68-77.

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Weiss, Benjamin P. "A Vitrage of Asteroid Magnetism." Science 338.6109 (2012): 897-898.

Klosterman, Michael J., and Peter R. Buseck. "Structural analysis of olivine in pallasitic meteorites: deformation in planetary interiors." Journal of Geophysical Research 78.32 (1973): 7581-7588.

Stevens, Michael R., David R. Bell, and Peter R. Buseck. "Tubular symplectic inclusions in olivine from the Fukang pallasite." Meteoritics & Planetary Science 45.5 (2010): 899-910.

Tarduno, John A., et al. "Evidence for a dynamo in the main group pallasite parent body." Science 338.6109 (2012): 939-942.

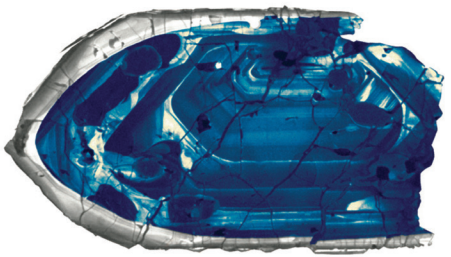
SPECIMEN TYPE:
ROCK & CRYSTAL

ESTIMATED AGE:
4,374,000,000 YEARS OLD

oldest earth

"The only physical evidence from the earliest phases of Earth's evolution comes from zircons."

– John Valley, Geoscientist



In addition to being the oldest known samples of Earth's crust, the zircons of the Jack Hills formation also contain water and the earliest suggestions of life in the form of biogenic carbon. As the science around this topic evolves, it may push back the starting point for life on Earth by hundreds of millions of years.

Left: Color-enhanced zircon crystal from Jack Hills. John valley, University of Wisconsin (Nature Geoscience 7, 2014).

Named for the fiery lord of the ancient greek underworld, the Hadean Eon (4.5-3.95Ga) describes a time when the Earth's surface was subject to widespread volcanism and continuous collisions with remnant objects in the chaotic early solar system.

It would seem an inhospitable place for water, let alone life. Yet our scientific understanding has changed quite a bit since the Hadean was first described in 1972.

We've learned that Earth must have possessed a significant amount of water during its early formation, and even though the heat was intense the atmospheric pressure of carbon dioxide kept water on the surface from boiling off. We also know that plate tectonics, the grinding of the crust, began during this time. Together these forces helped scrub the atmosphere of carbon dioxide and other greenhouse gases, leading to cooler surface temperatures and conditions favorable for life.

This history has been revealed by studying the chemical makeup of small crystals called zircons. Zircons are quite common in the crust of Earth. They are shed through the process of erosion once igneous rocks reach the surface, at which point the zircons are incorporated into new sedimentary layers.

In Australia, the rough, sedimentary layers of the Jack Hills formation are 3.3 billion years old, but they also contain much older zircons across a range of time from 3.6 to nearly 4.4 billion years old.

The specimen in the Mini Museum is a small piece of the Jack Hills formation north of

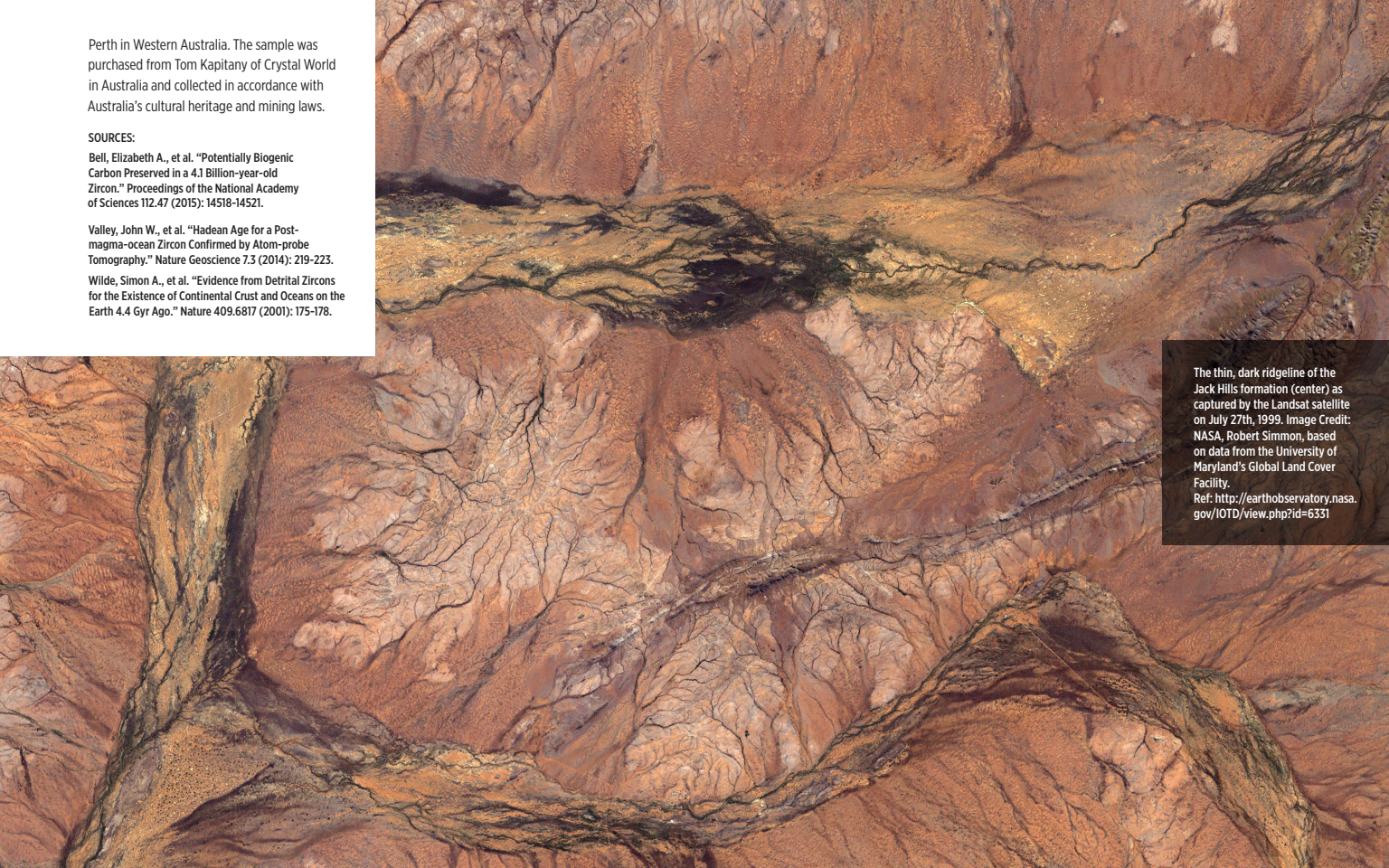
Perth in Western Australia. The sample was purchased from Tom Kapitany of Crystal World in Australia and collected in accordance with Australia's cultural heritage and mining laws.

SOURCES:

Bell, Elizabeth A., et al. "Potentially Biogenic Carbon Preserved in a 4.1 Billion-year-old Zircon." Proceedings of the National Academy of Sciences 112.47 (2015): 14518-14521.

Valley, John W., et al. "Hadean Age for a Post-magma-ocean Zircon Confirmed by Atom-probe Tomography." Nature Geoscience 7.3 (2014): 219-223.

Wilde, Simon A., et al. "Evidence from Detrital Zircons for the Existence of Continental Crust and Oceans on the Earth 4.4 Gyr Ago." Nature 409.6817 (2001): 175-178.

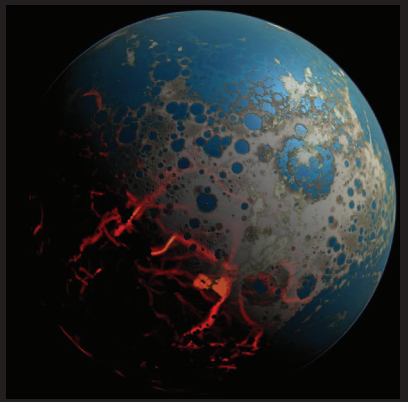


The thin, dark ridgeline of the Jack Hills formation (center) as captured by the Landsat satellite on July 27th, 1999. Image Credit: NASA, Robert Simmon, based on data from the University of Maryland's Global Land Cover Facility.
Ref: http://earthobservatory.nasa.gov/IOTD/view.php?id=6331

"A Breath Billions of Years in the Making"

In 2016, researchers at MIT pinpointed the peak of this change at 2.33Ga. A sharp drop-off followed, with a lull of a few hundred million years, then iron oxidation resumed with a final, small spike at 1.8Ga. The entire process took roughly 2,000,000,000 years, resulting in the oxygenated atmosphere that you and the many billions of creatures that came before have enjoyed.

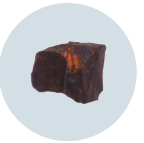
Photo credit: Simone Marchi



SPECIMEN TYPE:
ROCK

ESTIMATED DURATION:
3,800,000,000 - 1,800,000,000

ESTIMATED PEAK:
2,330,000,000



great oxygenation event

"Whenever I feel blue, I start breathing again."

– L. Frank Baum,
author of *The Wizard of Oz*

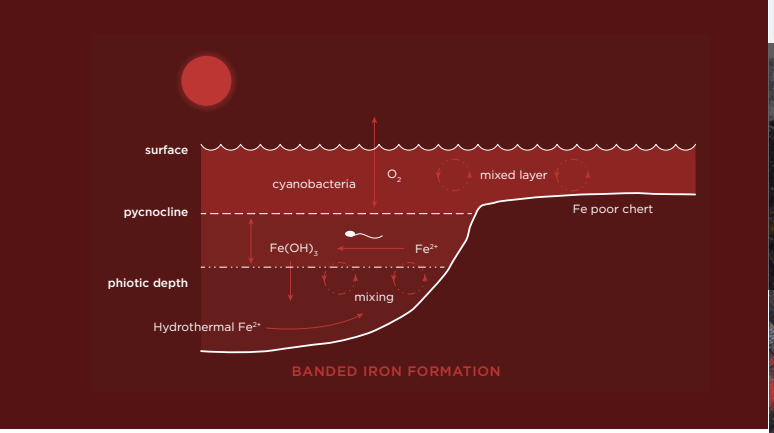
The average human being takes 20,000 breaths each day, but how often do we consider the processes that make this seemingly simple act possible? How did it all begin? From studying the striking colors of Banded Iron rock formations around the world, geologists have come to understand an incredible process that spanned nearly two billion years.

Banded Iron Formations contain thousands of millimeter and submillimeter-thick iron oxide layers interspersed with layers of silica. They are found all over the world.

The earliest Banded Iron Formations date to 3.8 billion years ago when the interior of the planet was still very hot, but the temperature on the iron-rich surface was not much different than it is today. The atmosphere contained little to no oxygen, but there was liquid water on the surface, even seas... and in the seas there was life.

Blue-green algae, also known as cyanobacteria, lived beneath near the surface of the early seas, living on energy produced from photosynthesis. In turn, their photosynthetic processes produced free oxygen which combined with iron carried from the surface into the sea by wind and erosion. The oxygen and the iron combined to form iron-oxides which drifted to the bottom and accumulated in layer after layer.

The formation of iron-oxides neutralized the excess oxygen in the water, allowing the cyanobacteria to thrive, multiply, and evolve. Yet, at times, the population of the cyanobacteria exceeded the balance of iron and the seas become toxic. Such mass



extinctions deprived the ocean of oxygen, resulting in new layers of iron-poor silica.

This steady process went on for over a billion years. Then, near the end of the Archean Eon, a period of geologic time lasting 1.5 billion years, there are several spikes in iron-oxide production which coincide with evidence of rapidly increasing atmospheric oxygen.

Life is clearly making strides, but the Earth itself is also changing.

Massive plumes rise within the mantle, creating volcanic hot spots and new continents. Sea levels rise alongside new mountains to unprecedented levels. All of this gives life the opportunity to push forward, a "Great Oxygenation Event" which results in a permanently oxygenated atmosphere and a chance for life to continue beyond the sea.

The specimen in the Mini Museum comes from Cleaverville Formation in Western Australia. Part of the George Creek Group from the west Pilbara, these deposits date to 3,020,000,000 years old.

SOURCES:

Luo, Genming, et al. "Rapid oxygenation of Earth's atmosphere 2.33 billion years ago." Science Advances 2.5 (2016): e1600134.

Holland, Heinrich D. "The oxygenation of the atmosphere and oceans." Philosophical Transactions of the Royal Society B: Biological Sciences 361.1470 (2006): 903-915.

Kappler, Andreas, et al. "Deposition of banded iron formations by anoxygenic phototrophic Fe (II)-oxidizing bacteria." Geology 33.11 (2005): 865-868.

Barley, Mark E., Andrey Bekker, and Bryan Krapež. "Late Archean to Early Paleoproterozoic global tectonics, environmental change and the rise of atmospheric oxygen." Earth and Planetary Science Letters 238.1 (2005): 156-171.

Left: Banded Iron Cycle: Cyanobacteria produce oxygen near the surface which feeds the iron oxidation process of proteobacteria at a deeper level. The iron is supplied by hydrothermal vents.

Below: Many thousands of sub-milimeter thick layers which make up the beauty of Banded Iron Formations.

The specimen in the Mini Museum comes from the bed of the Finke River. The river was free flowing when Hans collected the small soil sample, which is an unusual occurrence. We are greatly indebted to Hank Ebes for the generosity of his time in introducing Hans to the natural beauty of Central Australia.

SPECIMEN TYPE:
SAND

ESTIMATED AGE:
400,000,000-300,000,000 YEARS OLD

world's oldest river
(R. Finke)

"How the river has worn its way through a basalt range half a mile thick and 1,000 feet high is a mystery."

– Charles Chewing, *Sources of the Finke River* (1886)

The sinuous Finke River in Australia has mesmerized human beings for thousands of years. Aboriginal mythology ties the creation of the river's curves to the Rainbow Serpent which shaped the entire landscape of Australia after the Dreamtime when the world was flat and still. The deep incisions also confounded explorer Charles Chewing, who wrote the opening quote for this specimen in his landmark study of the Finke in 1886.

Rivers develop their curves through a direct relationship between the slope of the water's descent and the diameter of the particulate matter carried in its flow. Rivers which move through relatively flat terrain tend to develop very significant curves as the force of their passing waters push the flow around more dense soil deposits. By contrast, when a river flows down a steep hill, the banks tend to be straighter as the angle of descent is sharper.

The Finke River is something of an anomaly since its wildly meandering curves cut deep into the mountains and hills of Central Australia. This suggests that the river must be older than those hills which formed roughly 300-400 million years ago during a tectonic event known as the Alice Springs Orogeny.

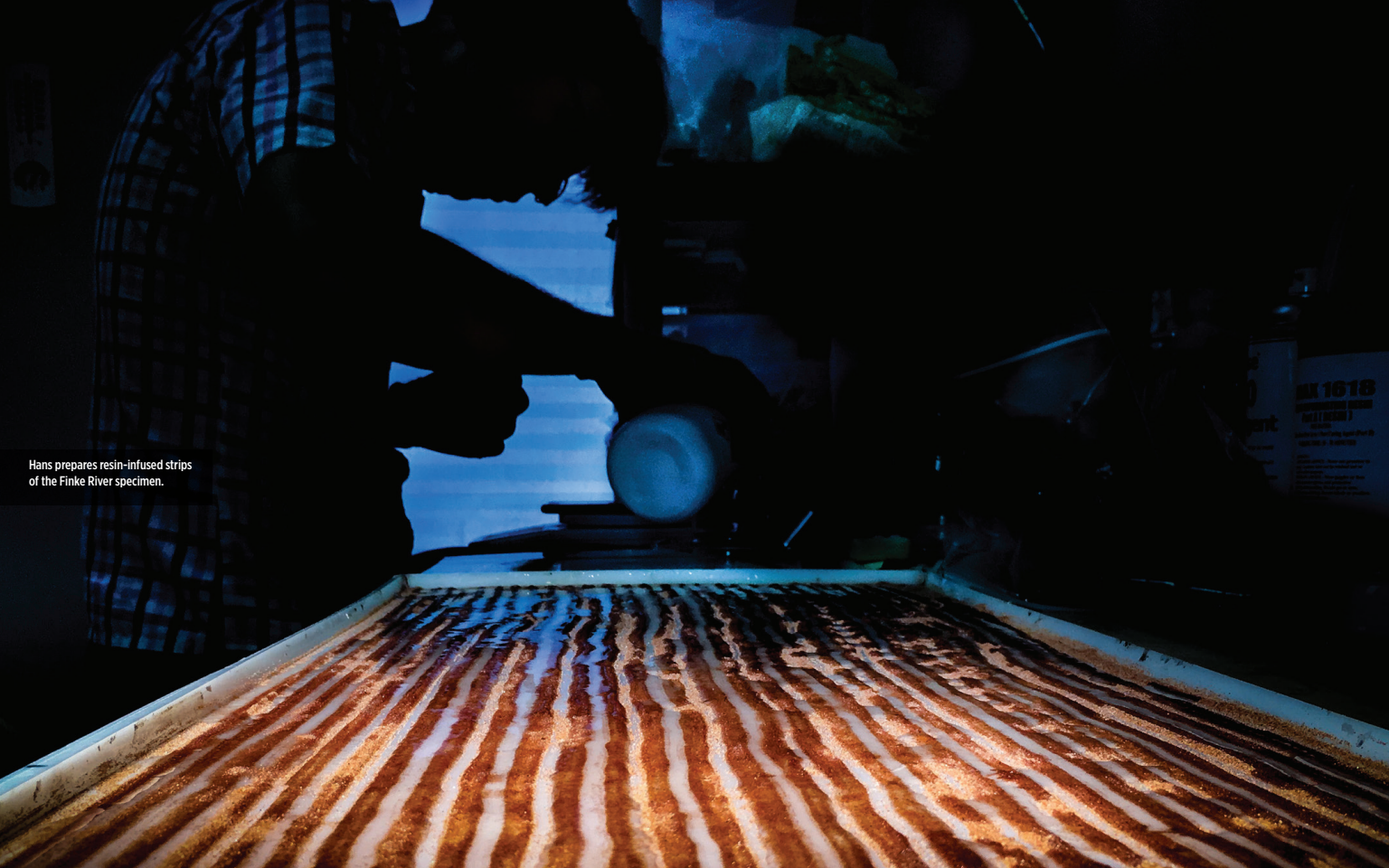
SOURCES:

Baker, Victor R. "Sinuous rivers." Proceedings of the National Academy of Sciences 110.21 (2013): 8321-8322.

Roberts, Emily A., and Gregory A. Houseman. "Geodynamics of central Australia during the intraplate Alice Springs Orogeny: thin viscous sheet models." Geological Society, London, Special Publications 184.1 (2001): 139-164.

Pickup, G., G. Allan, and Victor Baker. "History, palaeochannels and palaeofloods of the Finke River, central Australia." Academic Press. 1988.

Chewings, Charles. The sources of the Finke River. WK Thomas, 1886.Fujita, Eisuke, et al. "Stress field change around the Mount Fuji volcano magma system caused by the Tohoku megathrust earthquake, Japan." Bulletin of volcanology 75.1 (2013): 1-14.



Hans prepares resin-infused strips of the Finke River specimen.

Though well suited to sub-tropical climates, there are only pockets of *Araucaria* in the southern hemisphere today, primarily in Chile, Argentina, Australia, and the island of New Caledonia. Yet, during Jurassic Period, *Araucaria* could be found in great abundance across the world along with other gymnosperms and ferns.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE
TRIASSIC TO PRESENT

jurassic tree

"Araucaria was targeted as commonly available nutritious food source by many high-browsing megaherbivores."

– Jürgen Hummel,
Professor for Ruminant Nutrition,
Georg-August-University Göttinge

Over the last 200 million years, the "primitive" look of the *Araucaria* hasn't changed much. These conifers feature straight, columnar trunks and branches covered in overlapping, scale-like leaves. Most species of Araucaria tend to be quite tall, averaging 30-60 meters in height.

Recent digestive studies suggest that *Araucaria* is capable of yielding a surprising amount of energy when fermented for long periods. Taken together with *Araucaria*'s former range and physical characteristics, it should come as no surprise that scientists believe this conifer was a favorite food for long-necked sauropods.

The specimen in the Mini Museum is a fragment of *Araucaria* from Queensland, Australia located in strata dating to the Jurassic. The specimen was purchased from Tom Kapitany of Crystal World. It was collected in accordance with Australia's cultural heritage and mining laws.

SOURCES:

Gernandt, David S., et al. "The conifers (Pinophyta)." Genetics, genomics and breeding of conifers (2011): 1-39.

Chapman, Frank M. "Darwin's Chile." Geographical Journal (1926): 369-381.

Farjon, Aljos. A natural history of conifers. Timber Press, 2008.

Hummel, Jürgen, et al. "In vitro digestibility of fern and gymnosperm foliage: implications for sauropod feeding ecology and diet selection." Proceedings of the Royal Society of London B: Biological Sciences 275.1638 (2008): 1015-1021.

Weaver, Jan C. "The improbable endotherm: the energetics of the sauropod dinosaur Brachiosaurus." Paleobiology 9.02 (1983): 173-182.

Klein, Nicole, et al., eds. Biology of the sauropod dinosaurs: understanding the life of giants. Indiana University Press, 2011.

Rearing sauropods could reach higher foilage though the effort exerted great torque on their bodies.

Like many modern herbivores, sauropods are thought to have been ruminants. Ruminants acquire nutrients in cooperation with various microbes through a multi-step process of fermentation in a series of stomach-like chambers. This process allows the host animal to consume plants that would otherwise be undigestible to animals with simple stomachs.

Given their size, we can expect that sauropods would have longer digestive cycles. A longer fermentation period opens up the range of possible plants they could consume, including the tough but surprisingly energy-rich *Araucaria*.

Crinoid stems also worked their way in Christian legends in both Germany and England where they were known as St. Boniface's pfennige (pennies) and St. Cuthbert's beads. The latter is particularly interesting in the context of the Mini Museum as St. Cuthbert was a 7th century monk on the island of Lindisfarne off the coast of Northumberland. The Vikings raided this island in 793 just 100 years after the death of St. Cuthbert for whom the monastery there is named.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE
ORDOVICIAN (485,400,000)
TO PRESENT

crinoid

"It was the Law of the Sea, they said. Civilization ends at the waterline. Beyond that, we all enter the food chain, and not always right at the top."

– Hunter S. Thompson

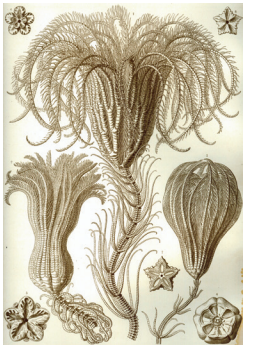
Sometimes referred to as feather stars or sea lilies, Crinoids are members of an extended and very ancient family of sea animals known as echinoderms. Echinoderms date back as far as the Cambrian period some 541,000,000 years ago. They include such varied animals as sea urchins, sea cucumbers, and starfish. Their development was part of a much larger explosion of complex life on Earth which resulted in most of the animal or metazoan body plans we know today.

Breaking down body plans into their simplest form involves looking at a concept known as symmetry. Symmetry in biology means that bodies can be divided in various ways which are more or less identical to each other.

There are three very basic forms of symmetry in biology: bi-lateral, spherical, and radial. Humans exhibit bi-lateral symmetry, with our bodies organized along a centerline. Spherical symmetry is generally limited to very small organisms like algae which form spherical colonies. The last form, called radial symmetry, is a bit like a pie where body parts are arranged around a main axis.

A number of variants to this radial symmetry exist wherein body parts are separated into four, five, six, or even eight symmetrical pieces. Echinoderms are the only animals that exhibit the five part, or pentaradial form of radial symmetry. This body plan also happens to result in interesting fossil shapes.

Living Crinoids are found in oceans all around the world.



Before they were identified as fossils, segmented Crinoid stems were sometimes referred to a "fairy money." This is not so different from the way other fossils were viewed, such as "snake stones" (fossil ammonites) or "snake tongues" (fossil shark teeth).

The specimen in the Mini Museum comes from the center of a crinoid stem, also known as a "columnal." It was recovered near Talsint, Morocco. The fossil beds in this region are from the Bajocian Age of the Middle Jurassic Epoch and date to roughly 170,000,000 years old.

SOURCES:

Kelley, Patricia, Michal Kowalewski, and Thor A. Hansen, eds. Predator-prey interactions in the fossil record. Vol. 20. Springer Science & Business Media, 2003.

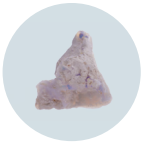
Hess, Hans, et al. Fossil crinoids. Cambridge University Press, 2003.

Chambers, Robert. The book of days, a miscellany of popular antiquities. 1862.

The Eromanga Basin in Central Australia was home to a great inland sea for about 95 million years during the Mesozoic Era. This sea was home to many forms of marine life including Plesiosaurs, Ichthyosaurs, and Ammonites.

SPECIMEN TYPE:
GEMSTONE

ESTIMATED AGE:
110,000,000 YEARS OLD



rough opal

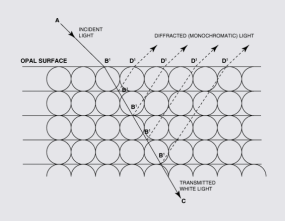
"Opals combine brilliant qualities of the most valuable gems and, above all, defy description."

– Pliny the Elder

A gemstone almost alive with an intense inner fire, opals have held the attention of humans for many thousands of years. From Egypt and Classical Greece to China and the Americas, ancient civilizations valued the beauty of opal, but it is only in recent history that we've come to understand the complex nature of this unique gemstone.

Unlike most gemstones, opal does not have a single crystalline lattice structure stretching throughout the material. Rather, opal is a collection of very tiny spheres of silicon-dioxide which are packed together and compressed. Scientists estimate it takes up to five million years to form a single centimeter of natural opal.

The "fire" of opal is the result of diffraction as light passes through the silicon-dioxide sphere within the stone.



As illustrated above, the spheres are aligned in an ordered network which continually diffracts the white light as it passes through each sphere and creates the shifting, brilliant colors we see.

Opal forms in areas where water comes in contact with sandstone and filters deep into the Earth, picking up more silica along the way. This silica-rich solution settles

into cracks, natural fractures in the rock, or even into fossilized organic material. Under the intense heat and pressure, most of the water evaporates leaving the silica behind.

The specimen in the Mini Museum is opalized fossil plant material from Lightning Ridge in New South Wales, Australia. Australia is the largest producer of opal in the world. The opal fields here date to the Cretaceous when Central Australia was home to an enormous inland sea, known to science as the Eromanga Basin.

SOURCES:

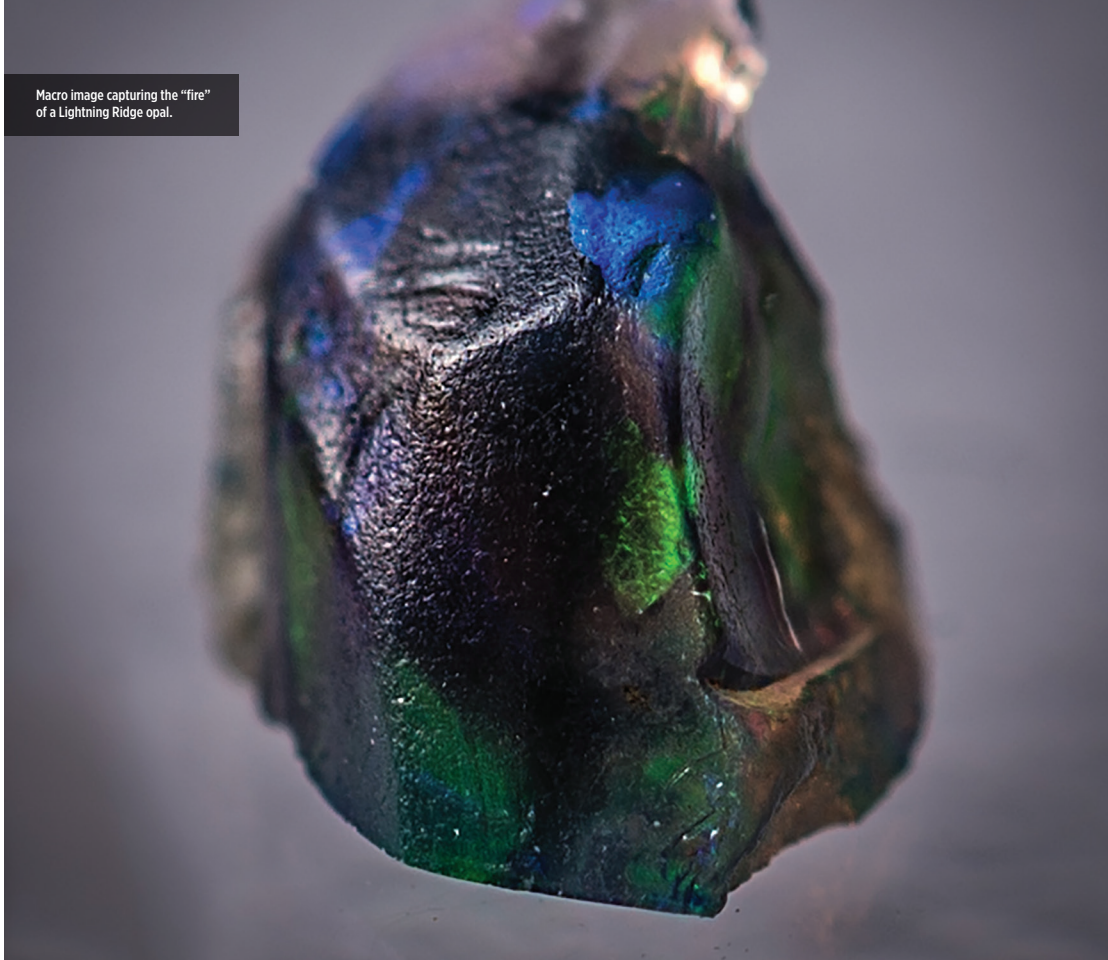
Eckert, Allan W. The world of opals. John Wiley & Sons, 1997.

Leechman, Frank. The Opal Book.

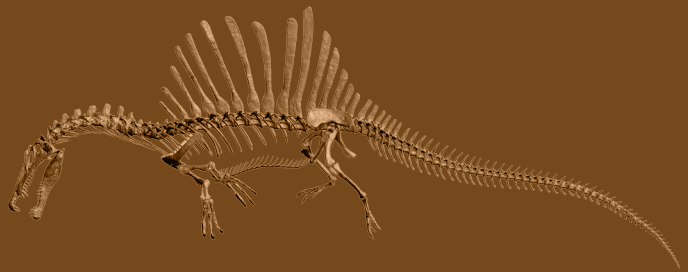
Kear, Benjamin P., Natalie I. Schroeder, and Michael SY Lee. "An archaic crested plesiosaur in opal from the Lower Cretaceous high-latitude deposits of Australia." Biology Letters 2.4 (2006): 615-619.

Pewkliang, Benjamath, Allan Pring, and Joël Brugger. "Opalisation of fossil bone and wood: clues to the formation of precious opal." Regolith, CRC LEME, Australia, h (2004): 264-268.

Keller, Peter C. Gemstones and their origins. Springer Science & Business Media, 2012.



Macro image capturing the "fire" of a Lightning Ridge opal.



Explorer and fossil collector Richard Markgraf discovered the first Spinosaurus remains in 1912 near the Bahariya Oasis in Western Egypt. At the time, Markgraf was working for German paleontologist Ernst Stromer. He sent the partial remains to Stromer in Munich who announced the discovery in 1915 and named the species *Spinosaurus aegyptiacus*.

In 1944, the allied bombing of Munich destroyed Erich Stromer's entire dinosaur collection including the original, or holotype, specimen *Spinosaurus aegyptiacus*.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
112,000,000 - 72,000,000

MAXIMUM KNOWN SIZE:
18M (59FT)

spinosaurus
(spine)

"Spinosaurus appears to have been poorly adapted to bipedal terrestrial locomotion. The forward position of the center of mass within the ribcage may have enhanced balance during foot-propelled locomotion in water."

– Nizar Ibrahim, Paleontologist, University of Chicago

Topping out at just over 18m long (59ft), Spinosaurus is one of the largest carnivorous dinosaurs ever discovered. This family of giant theropods also happens to be among the most surprising creatures in the fossil record.

Nearly everything about Spinosaurus defies traditional thoughts about carnivorous dinosaurs. To begin, Spinosaurids are the only known family of semi-aquatic dinosaurs. They also had long, narrow skulls, almost crocodile-like in appearance, and their jaws were lined with conical teeth instead of the curved, blade-like ziphodont teeth of most theropods.

Of course, Spinosaurus also had elongated neural spines forming a massive dorsal sail.

In some species, the spines in the namesake sail measure more than 2 meters in length, providing the framework for an impressive structure that would rise high above the water. The shape and function of this spine sail has been a hotly debated topic. Some theories suggest that the sail wasn't a sail at all but a "fatty-hump." However, a detailed reconstruction in 2014 concludes that the spines were too poorly vascularized to support such a structure and concludes that the spines were likely covered by skin and used for display. The same study also suggests that its limbs were somewhat shorter than previously thought, and appear to be specifically adapted to paddle-swimming like early whales.

The specimen in the Mini Museum comes from the Kem Kem Beds in Morocco. During the Cretaceous Period, this region was part of a vast river system. In recent years

Preparing Spinosaurus spine for inclusion.

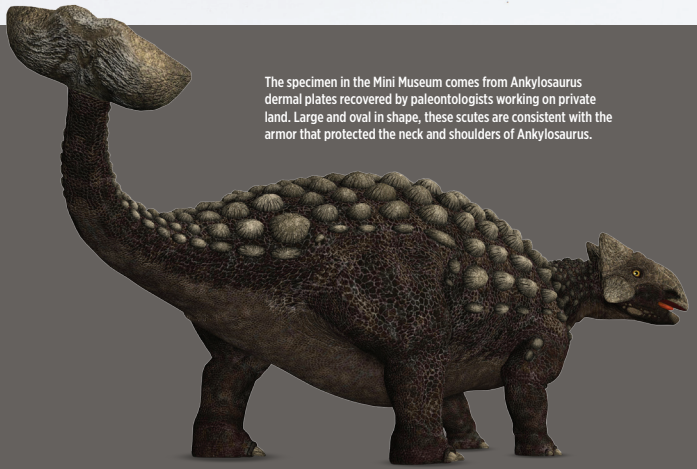
members of the Spinosaurus family have been found in many parts of the world including Europe, South America, and even Australia.

SOURCES:

Smith, Joshua B., et al. "New information regarding the holotype of Spinosaurus aegyptiacus Stromer, 1915." Journal of Paleontology 80.02 (2006): 400-406.

Stromer, Ernst. "Wirbeltier- Reste der Baharije-Stufe (unterstes Cenoman). 3. Das Original des Theropoden Spinosaurus aegyptiacus nov. gen. nov. spec." Abhandlungen der Königlichen Bayerischen Akademie der Wissenschaften, Mathematisch- Physikalische Klasse 28 (1915): 1-32.

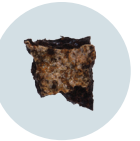
Ibrahim, Nizar, et al. "Semiaquatic adaptations in a giant predatory dinosaur." Science 345.6204 (2014): 1613-1616.



The specimen in the Mini Museum comes from Ankylosaurus dermal plates recovered by paleontologists working on private land. Large and oval in shape, these scutes are consistent with the armor that protected the neck and shoulders of Ankylosaurus.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
68,000,000-66,000,000



ankylosaurus

"The armor are bones that form within the skin, just like crocodiles."

– Ken Carpenter, Director USU Eastern Prehistoric Museum

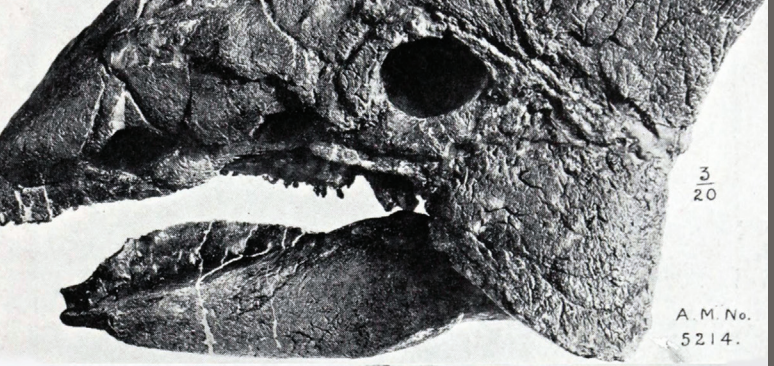
Built low to the ground and covered in rows of bony plates, Ankylosaurus is one of the most distinctive and successful of all dinosaur families. Spread across more than 90 million years of the fossil record, various species of this sturdy dinosaur can be found on every continent on earth.

Like most bony armor, the plates of an Ankylosaurus were not part of the skeleton, but rather formed within the skin. This type of growth is called an osteoderm. Osteoderms usually begin with small nodules of cartilage around which more dense material forms.

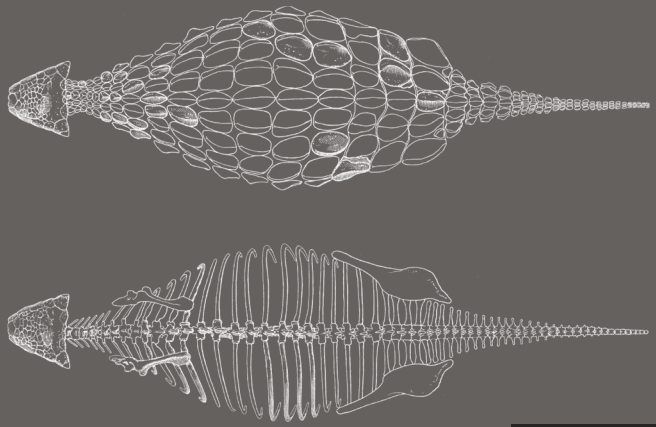
Osteoderms are found in many different and unrelated species from reptiles and amphibians to mammals, fish, and of course dinosaurs. They sometimes form fantastic structures such as the shells of the armadillo and glyptodon, or the tall, dorsal plates and tail spikes of Stegosaurus.

Recent studies have shown that most of the osteoderms on Ankylosaurus were relatively thin, and bound together by a complex arrangement of collagen fiber bundles. This structure kept the armor light and flexible as the plates grew larger and thickened over time. This finding is true even of the bony "tail clubs" found on some species.

Another interesting aspect of Ankylosaurus evolution is a progressive widening of the "hindgut" over time. The hindgut is broadly referred to as the lower part of the digestive system. In certain animals, this feature is highly developed, allowing for the extraction of nutrients from cellulose via



In Ankylosaurs, the armor also reshapes the skeleton as the animal grows into adulthood.



Skeletal reconstruction of Ankylosaurus with and without dermal armor.

microbial fermentation. An increase in the size of this feature over time might speak specifically to competitive pressure between different herbivorous dinosaur species such as the ceratopsids and hadrosaurids.

Like Ankylosaurus' armor, the hingut method of digestion is also found in other animals, including mammals. Scientists refer to such recurring features as signs of convergent evolution, where life develops similar responses to environmental pressures across vastly disparate species... not to mention time.

SOURCES:

Carpenter, Kenneth. "Redescription of Ankylosaurus magniventris Brown 1908 (Ankylosauridae) from the Upper Cretaceous of the Western Interior of North America." Canadian Journal of Earth Sciences 41.8 (2004): 961-986.

Yang, Wen, et al. "Natural flexible dermal armor." Advanced Materials 25.1 (2013): 31-48.

Scheyer, Torsten M., and P. Martin Sander. "Histology of ankylosaur osteoderms: implications for systematics and function." Journal of Vertebrate Paleontology 24.4 (2004): 874-893.

Once thought to be almost crocodile-like in appearance or even related directly to snakes, recent studies have revised our understanding of Mosasaurs giving way to a picture of a streamlined predator well-suited to dominating its environment.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
92,000,000 - 66,000,000

mosasaur

"A swift and powerful swimmer over short distances, the Mosasaur used surprise and the thrust of his muscular tail to outrun his prey with a short burst of speed."

– Michael J. Everhart, *Oceans of Kansas (2005)*

If we look first to the sea, the Mesozoic Era might not be known as the Age of Dinosaurs, but rather as the Age of Marine Reptiles. Beginning with the appearance of the dolphin-shaped Ichthyosaurs in the Triassic Period, the rising seas of the Jurassic Period gave way to a wider variety of large predators including the long-necked Plesiosaurs and Pliosaurs to the powerful Mosasaurs.

Since the first Mosasaur skull was discovered in 1764, our knowledge of this large family of marine reptiles has come primarily from skeletal remains. Mosasaurs ranged in size from 1.1m (3.3ft) to 17.4m (57 ft). Their skulls were flexible and their jaws are double-hinged. While this arrangement probably allowed a Mosasaur to swallow prey whole, the alignment of a Mosasaur's teeth with "bony crypts" to protect emerging teeth also suggests Mosasaurs likely crushed bones as frequently as they tore into flesh.

While this evidence alone suggests the Mosasaurs were formidable predators, a spectacular new find in Jordan has revealed that Mosasaurs were "countershaded" with darker pigmentation on the top and lighter on the bottom. Similar soft tissue impressions show that Mosasaurs have tail flukes and true flippers. This new information suggests this already formidable predator could swim much faster, a truly terrifying presence backed long history in the fossil record.

The specimen in the Mini Museum comes from the muzzle of a juvenile *Tylosaurus proriger*. This species typically grew to a length of 15m (50ft). The specimen was collected on private land in Western Kansas.

SOURCES:

Lindgren, Johan, et al. “Skin pigmentation provides evidence of convergent melanism in extinct marine reptiles.” Nature (2014).

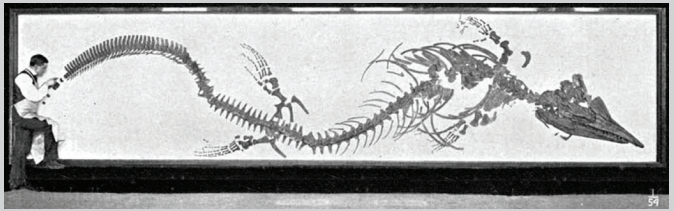
Liu, Min, et al. “Varanoid Tooth Eruption and Implantation Modes in a Late Cretaceous Mosasaur.” Frontiers in physiology 7 (2016).

Cope, Edward Drinker. The primary factors of organic evolution. Open Court, 1904.

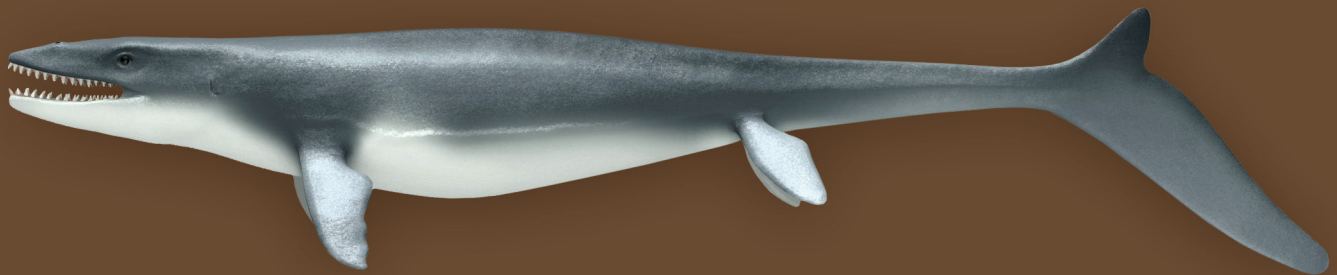
Cope, Edward Drinker. “Lamarek versus Weismann.” Nature 41 (1889): 79.

Lindgren, Johan, et al. “Convergent evolution in aquatic tetrapods: insights from an exceptional fossil mosasaur.” PLoS One 5.8 (2010): e11998.

Everhart, Michael J. Oceans of Kansas. Indiana University Press, 2005.



Clockwise from the left: Mosasaur tooth eruption; Complete skeleton of *Tylosaurus dyspelor*. H.F. Osborne (1899); Mosasaur illustration by Stefan Sølberg.

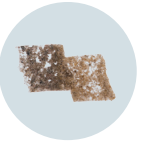


The geological record reveals that large earthquakes like the 1906 quake strike along the San Andreas Fault every 150 years or so. To model the potential damage from such a quake along the southernmost section of the fault, the USGS modeled a 7.8 magnitude "Shake Out" scenario in 2008. This model estimates damage from such a quake may run as high as $213 billion US dollars and might cost 1800 people their lives.

SPECIMEN TYPE:
ROCK

ESTIMATED AGE:
28,000,0000 YEARS OLD

LENGTH OF THE FAULT:
800 MILES (1300KM)



san andreas fault

"Big earthquakes on the San Andreas Fault are inevitable, and by geologic standards extremely common."

– Lucile M. Jones, USGS ShakeOut Scenario (2008)

On the morning of April 18th, 1906, a powerful earthquake woke the city of San Francisco at precisely 5:12AM. Fires resulting from the quake destroyed 80% of the city, killing more than 3,000 people and leaving hundreds of thousands homeless. It was as violent an introduction as one could imagine to the presence of the 28 million year-old San Andreas Fault.

Known as a transform boundary, the edges of the San Andreas Fault slip past each other in a horizontal fashion. In the case of the 1906 earthquake, it took less than five seconds for the Pacific and North American plates to slip 20 feet past each other along a 296 mile rupture.

Disconcerting as this may be, the 1906 quake is not the largest quake possible along the San Andreas or even the largest that's occurred in the past. All along the fault's 1300km (800mi) spine, we can see the history of two continental plates grinding past each other.

To understand the destructive potential of this fault, it's helpful to take a look into the deep history of the forces that have helped shape the western quarter of North America.

Nearly all of the land here was accumulated over the course of 200,000,000 million years as one ancient, oceanic plate known as the Farallon Plate slowly sank beneath the North American Continental Plate. Great slabs of rock peeled off in sheets. Under the intense pressure, these terranes became sutured together and formed new land. When the central portion of the Farallon Plate finally slipped all the way under the North American Plate, the Pacific Plate came

Contact between continental plates exposed in Tejon Pass.

into contact with the North American Plate for the first time, forming the San Andreas Fault.

The specimen in the Mini Museum was recovered from the Tejon Pass, where the interface between the North American and Pacific plates are directly exposed and easily accessible. Each specimen is comprised of parts of both plates.

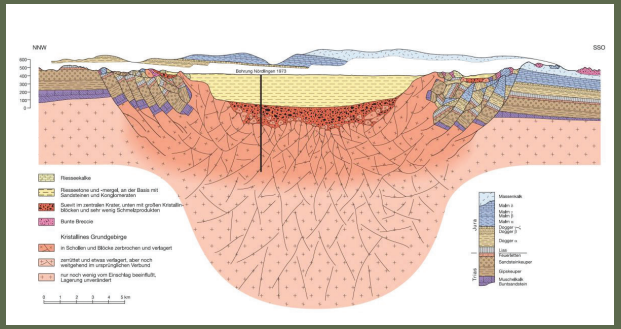
SOURCES:

Winchester, Simon. A Crack in the Edge of the World: the Great American Earthquake of 1906. Penguin UK, 2006.

Lynch, David K. Field guide to the San Andreas Fault. Thule Scientific, 2006.

Jones, Lucile M., et al. "The shakeout scenario." US Geological Survey Open-File Report 1150 (2008): 308.

Geological cross-section of the Reis Crater illustrating the many layers of material created at impact from the Bavarian State Office for the Environment (2016).



SPECIMEN TYPE:
IMPACT MELT

ESTIMATED AGE:
14,400,000 YEARS OLD

moldavite

"In its oddness, it reminds one of the strange ring mountains of the Moon, and it is easy to think that the origins of these as well as of the Reis Basin are due to the same causes."

– Ernest Werner, amateur Geologist and the first to suggest Reis basin origin is not volcanic (1904)

For many years, a pastoral region of southern Germany was thought to be the remains of an ancient volcanic crater. Imagine the surprise when it was discovered that the Nördlingen Ries Basin was in fact an asteroid impact site some 14,400,000 years earlier.

In an instant, a 1.5km wide asteroid released 2.4×10^21 jjoules - enough energy to power the entire modern human world for more than six years. This tremendous blast gouged out hundreds of cubic kilometers of material and created created a complex array of materials, from new metamorphic rocks studded with impact diamonds to stunning, green gems called Moldavite.

Current research suggests Moldavite was created at the very instant of impact when layers of surface rock vaporized and mingled with the remains of the impact body. Essentially molten glass, this vitreous substance cooled in flight and rained in an east-northeast arc 450km from the impact site.

Nearer to the crater, a dense ejecta blanket formed from a mélange or breccia of sedimentary rock. Pockets of Suevite formed as well. Suevite is a metamorphic rock composed of ancient "basement layer" rocks, granite and gneiss, shocked by the intense release of energy and recombined. The power released was enough to instantly form millions of micro-diamonds.

After the impact, a deep, alkaline lake formed in the crater, following a path from supersaline to freshwater over many millennia. The change to freshwater was due to erosion of the crater rim and the eventual formation of an outlet lake. Today, the lake is gone, but even millions of years later the remains

of the crater (24km wide and 100-150m deep) speak to the power of the impact.

The specimen in the Mini Museum comes from Moldavites found in the Bohemia region of the western Czech Republic. 99% of all Moldavites come from this region.

SOURCES:

Shoemaker, Eugene M., and Edward CT Chao. "New evidence for the impact origin of the Ries Basin, Bavaria, Germany." Journal of Geophysical Research 66.10 (1961): 3371-3378.

Pohl, Jean, et al. "The Ries impact crater." Impact and explosion cratering: Planetary and terrestrial implications. Vol. 1. 1977.

Stähle, Volker. "Impact glasses from the suevite of the Nördlinger Ries." Earth and Planetary Science Letters 17.1 (1972): 275-293.

Okeefe, J. A. "Tektites and the Moon." (1961).

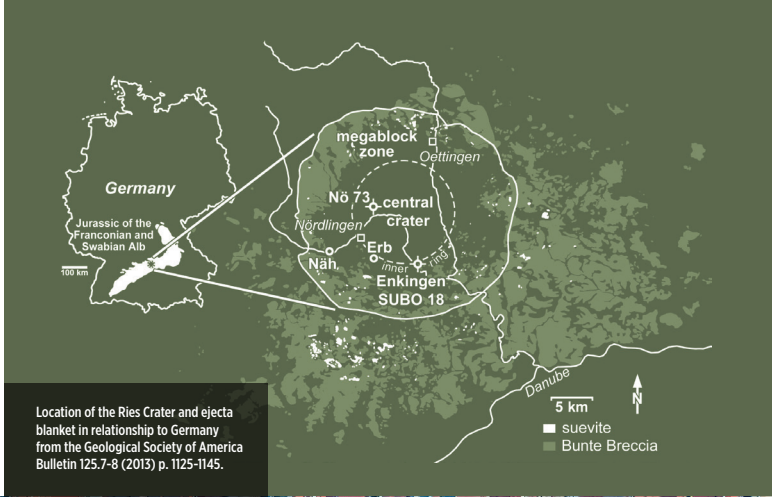
Osinski, G. R. "The Fate of Carbonates During the Formation of the Ries Impact Structure, Germany." Lunar and Planetary Science Conference. Vol. 45. 2014.

Arp, Gernot, et al. "Chemical and ecological evolution of the Miocene Ries impact crater lake, Germany: A reinterpretation based on the Enkingen (SUBO 18) drill core." Geological Society of America Bulletin 125.7-8 (2013): 1125-1145.

Stöffler, Dieter, Natalia A. Artemieva, and Elisabetta Pierazzo. "Modeling the Ries- Steinheim impact event and the formation of the moldavite strewn field." Meteoritics & Planetary Science 37.12 (2002): 1893-1907.

Stöffler, Dieter, et al. "Ries crater and suevite revisited—Observations and modeling Part I: Observations." Meteoritics & Planetary Science 48.4 (2013): 515-589.

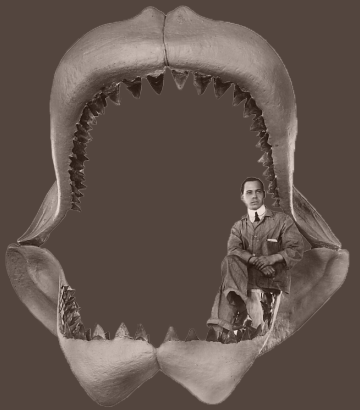
Artemieva, N. A., et al. "Ries crater and suevite revisited—Observations and modeling Part II: Modeling." Meteoritics & Planetary Science 48.4 (2013): 590-627.



Location of the Ries Crater and ejecta blanket in relationship to Germany from the Geological Society of America Bulletin 125.7-8 (2013) p. 1125-1145.

The medieval town of Nördlingen sits near the center of the Nördlingen Ries crater. Most of the town is built of Suevite and the "Bunte Breccia" formed during the impact, including the gothic, 15th century *Georgskirche* (top center). If the town looks familiar it may be due to the fact that it served as the backdrop for the final flyover scene at the end of *Willy Wonka and the Chocolate Factory* (1971).

The history of fossilized sharks teeth is rather surprising. Pliny the Elder, the Roman naturalist, recorded the belief that Glossopetra or "tongue stones" fell from the sky during lunar eclipses. Early Christians believed these tongue stones to be the tongues of serpents turned to stone by Saint Paul when he visited the Islands of Malta, and that the stones were useful as a protection against snake venom and other poisons. This changed in the 17th century when the Italian naturalist, Fabio Colonna, recognized them as sharks' teeth. Later, the great Nicolaus Steno, who would go on to become one of the founders of stratigraphy and modern geology, illustrated the head in this picture including a Megalodon tooth once thought to be a precious "tongue stone."



SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
23,000,000–2,600,000 YEARS AGO

megalodon
(tooth)

"You're gonna need a bigger boat."

– Roy Scheider as Police Chief Martin Brody, **Jaws** (1975)

The Megalodon shark dominated the oceans of the world for over 20 million years. Reaching sizes upwards of 18m (59ft) in length, the largest Megalodon jaw reconstruction measures 3.3m (11ft) across and 2.7m (9ft tall). Computer models suggest that a full-grown Megalodon had the most powerful bite of any known animal in the fossil record, somewhere between 11 and 18 tonnes or 25,000-40,000 pounds. This epic jaw was also lined with enormous teeth - 46 in the front row, to be exact, with 5 more rows waiting behind.

The fossil record suggests that Megalodon fed on a wide variety of prey. Smaller marine mammals, like dolphins, seals, and manatees were obvious targets, but even the largest early whales were not safe from this enormous apex predator. Analysis suggests that Megalodon was likely a very intelligent hunter, disabling large whales by crushing flippers or piercing internal organs. Recent studies of developing populations of predatory whales also suggest that pack hunting behavior may have developed as a competitive response to Megalodon's dominance.

Finding a home for Megalodon in the hierarchy of sharks has been an interesting task for science. For years, two competing branches of the shark family laid claim to this monster, the *Carcharodon* or the white-shark line, and the now extinct line of "megatooth" sharks of *Carcharocles*. These two branches of the shark family had radically different feeding patterns. The megatooth sharks specialized in hunting whales and sirenians (manatees) in warmer waters, while the white-shark line focused on colder climate hunting, a practice

Megalodon jaw reconstruction using fossilized teeth.

Megalodon tooth fragments both before and after cleaning.

that continues today as young great white sharks switch from fish to seals as they mature.

The debate is still ongoing but most scientists have settled on the megatooth-line based on the feeding pattern of Megalodon. Not surprisingly, the extinction of the Megalodon roughly two million years ago is tied directly to the mega-sizing of modern baleen whales.

The specimen in the Mini Museum comes from the fossilized tooth enamel of a Megalodon shark. The teeth come from the coastal rivers of South Carolina, one of the most popular regions for hunting Megalodon teeth. Megalodon teeth are found in several regions of the world, primarily areas which would harbor the warmer seas of their preferred prey. The coloring of the fossils reflects the different minerals present in the sediment when the teeth were deposited.

SOURCES:

Pimiento, Catalina, and Christopher F. Clements. "When did Carcharocles megalodon become extinct? A new analysis of the fossil record." PloS one 9.10 (2014): e111086.

Cajus, G. "Evolution of white and megatooth sharks, and evidence for early predation on seals, sirenians, and whales." Natural Science 2013 (2013).

Eilperin, Juliet. Demon fish: travels through the hidden world of sharks. Anchor, 2012.

SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
4,800,000 - 11,000 YEARS AGO

giant sloth
(claw)

"I will venture to refer to him by the name of the Great-Claw..."

- Thomas Jefferson (1799)

Like other Pleistocene Epoch megafauna, the giant sloths disappeared from the mainland about 11-12,000 years ago. Small pockets remained on islands of the Caribbean until they too disappeared 3000 years ago. The spread of modern humans is generally blamed for this mass extinction event, but the latest research has tended to look towards climate change as the main culprit.

Often known for their great claws and ungainly appearance, ground sloths were a very successful family of mammals.

Originating in South America, smaller species of ground sloth made their first appearance in the fossil record during the Oligocene Epoch 35 million years ago. Over millions of years in relative isolation, sloths grew in size becoming true giants only eclipsed by the mammoths.

The largest known species evolved during the Pliocene epoch in the midst of a period of great migration between North and South America. This "Great American Interchange" lasted millions of years, beginning with island hopping and peaking as animals crossed freely over the newly formed isthmus of Panama.

Roughly three million years later, in 1788, the first fossil remains of *Megatherium* were discovered in Argentina and shipped to the Royal Cabinet of Natural History in Madrid, Spain. Drawings of the assembled skeleton soon reached the great French anatomist, Georges Cuvier, who identified the animal as a type of sloth. Cuvier originally thought the claws were used for climbing trees, but due to the animal's great size he changed his hypothesis settling on a ground or subterranean existence.

Modern studies of giant sloth skeletons and trackways found in Argentina and Nevada place the average top speed of the largest ground sloths at 1.68 meters per second or 3.7 miles per hour. This is an average walking speed for most humans so it would seem the sloths were easy prey. However most ground sloths also possessed bony growths within the skin

Cancellous or "spongy" bone structure of the Giant Sloth claw.

known as osteoderms. Even humans armed with the best technology of the time would have difficulty penetrating this thick armor at a distance, which meant getting in reach of this powerful animal's enormous claws.

The specimen in the Mini Museum comes from the tip of an *Eremotherium* claw, discovered on private land and partially restored by George Heslep. *Eremotherium* stood roughly 4m tall (20ft) and weighed 3,000 kilograms (6,600lbs). Many species of giant sloths have been found throughout both North and South America, including a fossil described by Thomas Jefferson in 1799.

SOURCES:

Blanco, R. Ernesto, and A. Czerwonogora. "The gait of Megatherium Cuvier 1796." Senckenb biol 83 (2003): 61-68.

Cuvier, Georges. "Fossil Bones and Geological Catastrophes." New Translations and Interpretations of the Primary Texts 301 (1997).

Cartelle, Cástor, and Gerardo De Iuliis. "Eremotherium laurillardi: the Panamerican late Pleistocene megatheriid sloth." Journal of Vertebrate Paleontology 15.4 (1995): 830-841.

Jefferson, Thomas. "A memoir on the discovery of certain bones of a quadruped of the clawed kind in the western parts of Virginia." Transactions of the American Philosophical Society 4 (1799): 246-260.

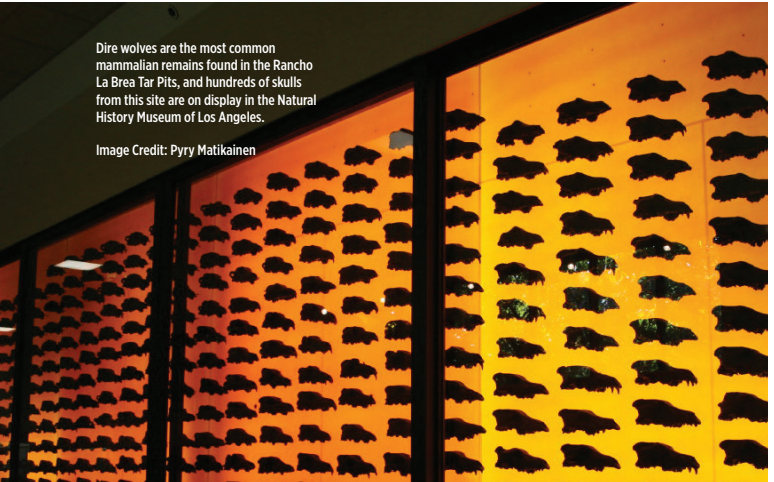
SPECIMEN TYPE:
FOSSIL

TEMPORAL RANGE:
250,000-10,000 YEARS AGO

dire wolf

"Let me tell you something about wolves, child. When the snows fall and the white winds blow, the lone wolf dies but the pack survives."

– George R.R. Martin,
A Song of Ice and Fire



Dire wolves are the most common mammalian remains found in the Rancho La Brea Tar Pits, and hundreds of skulls from this site are on display in the Natural History Museum of Los Angeles.

Image Credit: Pyry Matikainen

The dire wolf was one of the most successful predators of the late Pleistocene epoch. Ranging from Alaska to Bolivia, this muscular carnivore fed on a wide variety of large prey including bison, camels, horses, mastodons, mammoths, and even giant ground sloths.

The first remains of the dire wolf were discovered on the banks of the Ohio River near Evansville, Indiana, and later identified as a new species (*Canis dirus*) by Joseph P. Leidy. Leidy's early remarks to the Academy of Natural Sciences in Philadelphia in 1854, describe an animal that is strikingly similar to the modern gray wolf:

"The fragment only differs from the corresponding part of the recent Canis lupus Europe and its American congeners, in being rather larger and in its having slight variations in several of the molar teeth."

Even though these two animals stood roughly the same height at the shoulder, the dire wolf's bones are far thicker, and the skull, including the jaws and teeth, is much larger. Modern estimates of body mass based on skeletal reconstruction suggest the average dire wolf outweighed its gray wolf cousin by 40% or more. The increased strength would be very useful in wearing down larger prey. It also suggests that dire wolves might have been more physical in their approach to hunting, using body weight as a major advantage.

The dire wolf is thought to have been a pack hunter. This finding is based in part on analysis of remains found at Rancho La Brea Tar Pits where the dire wolf outnumbers other large mammals nearly ten to one. This also suggests

that dire wolves hunted in much larger packs than the gray wolf, which would not be too surprising given the size difference between the dire wolf and its megafaunal prey.

Yet, despite the dire wolf's advantages in size and numbers, it disappeared along with many other large species at the end of the Pleistocene epoch. Most scientists believe that rapid climate change played a major role in this large scale extinction event, but it would be difficult to ignore the introduction of humans to the Americas as the two species often sought the same prey.

The specimen in the Mini Museum comes from the partial remains of a dire wolf found in Florida on private land.

SOURCES:

Leonard, Jennifer A., et al. "Megafaunal extinctions and the disappearance of a specialized wolf ecomorph." Current Biology 17.13 (2007): 1146-1150.

VanValkenburgh, Blaire, and Fritz Hertel. "Tough times at La Brea: tooth breakage in large carnivores of the late Pleistocene." Science 261.5120 (1993): 456-459.

Wroe, Stephen, Colin McHenry, and Jeffrey Thomason. "Bite club: comparative bite force in big biting mammals and the prediction of predatory behaviour in fossil taxa." Proceedings of the Royal Society of London B: Biological Sciences 272.1563 (2005): 619-625.

Leidy, Joseph. "Notice of some fossil bones discovered by Mr. Francis A. Lincke, in the banks of the Ohio River, Indiana." Proceedings: Academy of Natural Sciences of Philadelphia 7 (1854): 199-201.

Meachen, Julie A., Alexandria L. Brannick, and Trent J. Fry. "Extinct Beringian wolf morphotype found in the continental US has implications for wolf migration and evolution." Ecology and evolution 6.10 (2016): 3430-3438.

Leader of the Pack: While the Dire Wolf was the dominant wolf of its day, several species inhabited North America at the same time. Massive ice sheets above the 42nd parallel periodically opened and closed, allowing smaller wolves like the Beringian wolf to infiltrate the Dire Wolf's territory to the south.

Papyrus grows in tufted clumps in warm, marshy soil. The protein-rich roots can be boiled and eaten. The stalks are very strong when bound together and were used to build boats, woven into sandals and baskets, and used for any number of products including papyrus paper. Papyrus paper rivaled linen as a chief commercial export from Egypt and evidence suggests this writing material was in use for over 5,000 years.

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED USE IN HUMAN HISTORY:
5,000 YEARS

egyptian papyrus

"Before we leave Egypt we shall also describe the nature of papyrus, since our civilization or at all events our records depend very largely on the employment of paper."

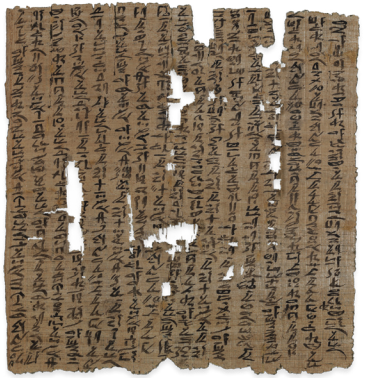
– Pliny the Elder

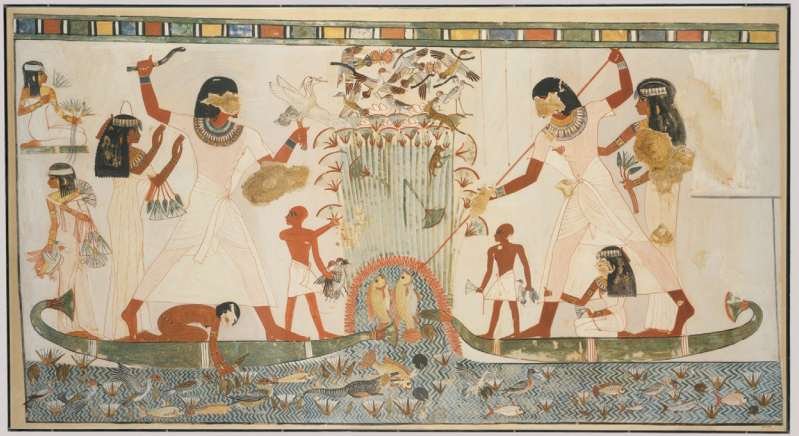
In ancient Egyptian cosmology, the world began as dry land emerged from the primeval waters. The darkness of the world was filled with light, and there in the marshy soil the papyrus grew. From this creation myth, the humble papyrus went on to serve as the symbol of life in Egypt for millennia. Yet, while ceilings of temples were held aloft by columns shaped like papyrus stems, the papyrus was far more than a religious symbol to the Egyptians; it was one source of their impressive commercial power in the ancient world.

Given the enormous importance of papyrus paper, it should come as no surprise that the manufacturing process was a closely guarded state secret. The royal monarchy maintained such strict control of the industry that the first surviving record of the manufacturing method doesn't appear until the first century CE, during the height of the Roman Empire.

In his *Naturalis Historia*, Pliny the Elder (23-79CE) describes a very labor intensive process in which pith was removed from the center of the stalk and cut into thin strips. The strips were placed side by side and then a second layer was added perpendicular to the first. Muddy water from the Nile was applied as a binding agent and the layers were hammered together. After drying under pressure, these sheets were bound or pasted to form long scrolls.

Modern chemical investigations of the binding properties of the papyrus plant indicate that no glues were actually needed. While papyrus contains very little starch or raw sugars, research suggest that long chains of fructose molecules known as fructans are





Famous papyri from the Metropolitan Museum of Art (clockwise from the top left): Heqanakht Letter I (c. 1961–1917 BCE); The Singer of Amun Nany's Funerary Papyrus (c. 1050 BCE); Menna and Family Hunting in the Marshes, Tomb of Menna (c. 1400–1352 BCE)

indeed present. Boiling the papyrus stalks would likely allow these fructans to serve as the binding agent. Laboratory tests show that this type of natural papyrus paper is both more supple and durable than any made with glue or other natural binding agents.

The specimen in the Mini Museum comes from a selection of fragmented papyri collected over many years by a German dealer of antiquities.

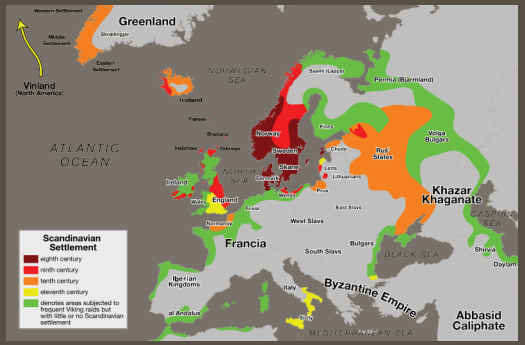
There are many great papyri collections around the world. The Austrian National Library has one of the largest collections with some 180,000 items spanning 3,000 years and written in many languages including: Middle Egyptian, written in hieroglyphs and hieratic; demotic; Coptic; Greek; Latin; Hebrew; Syriac, Aramaic, Pehlevi (Middle Persian); and Arabic.

SOURCES:

Gaudet, J. "Papyrus, the Plant that Changed the World– From Ancient Egypt to Today's Water Wars." (2014).

Scora, PETER E., and RAINER W. Scora. "Some observations on the nature of Papyrus bonding." Journal of Ethnobiology 11 (1991): 193-202.

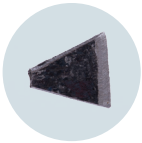
Bagnall, Roger S. The Oxford handbook of papyrology. Oxford University Press on Demand, 2009.



More than 1200 years ago the Vikings left the fjords of modern Scandinavia and set out to sea. Today, nearly every country in Europe has a story to tell of the Viking expansion, and a complex history of their many societies is slowly being rediscovered.

SPECIMEN TYPE:
HUMAN ARTIFACT

ESTIMATED AGE:
C. 10TH CENTURY CE



viking axe

"Never before has such terror appeared in Britain as we have now suffered from a pagan race ... The heathens poured out the blood of saints around the altar, and trampled on the bodies of saints in the temple of God, like dung in the streets."

– Alcuin of York, on the first Viking raids of 793

The spectacular entry of the Vikings into history is usually pinned to a raid on an isolated monastery off the northeast coast of England in 793 CE. The raid received wide attention in Western Europe due to the writings of a prominent scholar named Alcuin of York. A native to this region of England, Alcuin was serving in the court of Charlemagne when he received word of the raid. Yet, Alcuin's rather graphic description is complicated by the times in which it was crafted. The growing empire of Charlemagne had come into contact with the Danes to the north and there are some scholars who suggest that the raid on Lindisfarne monastery, and many of the others which followed, were in direct response to the threat the Norsemen felt along their own borders.

Regardless, the expansion of the Norsemen continued, and their travels were widespread. They scouted and raided the entire coast of Europe and all of the major rivers of the continent. During their time in southern and eastern Europe, Norsemen served as mercenaries for the Byzantine Empire and enforcers of the peace in Slavic lands. They expanded far to the East, establishing colonies in today's Russia. The Kievan Rus, as they were known, also traded with the Islamic world. Rare evidence of this extensive trade network was discovered in the 19th century when a ring bearing Arabic script was uncovered in the 9th century grave of a woman on the Swedish island of Björkö.

Blacksmiths of Baltimore Knife & Sword during early stages of preparation

In the north Atlantic, Norsemen discovered the island of Iceland, the archipelago of Svalbard, and the micro-continent Greenland. They also made several attempts to colonize a land further west which they called Vinland and which we call North America.

Records of these adventures and Norse society were often kept in literary form known as a Saga. When we hear the word "Saga" today, we often think of the "Prose Edda" which contains many of the mythological stories we associate with the notion of the Vikings. However, the Saga was really more of a broad term used to describe nearly any narrative.

In addition to the adventures, family histories, mythology, and tales of political intrigue, the Sagas also describe the weapons of the Vikings and their manufacture. Next to the knives, the machete-like sax, and the swords of the wealthy, we also learn more about the various types of axes that were so prominent in the lives of the Norsemen.

Unlike the popular image of a giant Viking axe, the reality is quite different. Smaller blades were more effective in close combat not to mention much cheaper. So, while the largest axes like the crescent-shaped Breiðøx, or broad axe, might have a cutting edge up to 18" (45cm), the iconic "bearded axe," or Skegøx, might only reach at most 6" (15cm).

The bearded axe was a versatile tool and common across the Viking world. In combat, the "beard" could be used used to hook an opponent and even helped scale wooden fortifications. The style was also very common in woodworking tools as well.

With a properly sharpened carving axe, a skilled craftsman can quickly turn out many useful implements including mallets, bowls, and even spoons. Combined with the adze, the gouge, and the drawknife, it is possible to create incredibly ornate carvings including the famous dragon heads which adorned the prows of many Norse sailing ships.

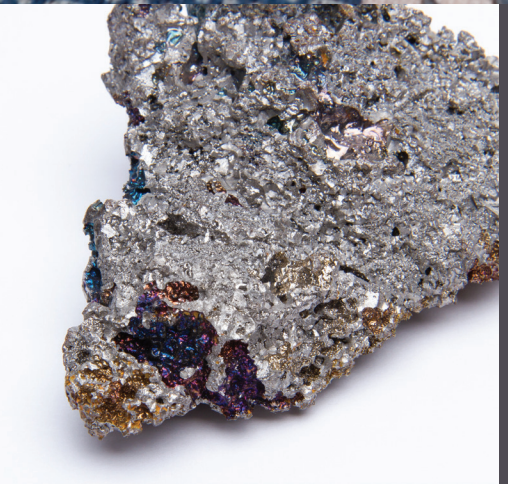
The specimen in the Mini Museum comes from a Viking bearded axe. By the style, the axes are dated to 900 CE.

SOURCES:

Pye, Michael. The Edge of the World: How the North Sea Made Us who We are. Penguin UK, 2014.

Haywood, John. The Penguin historical atlas of the Vikings. Penguin Group USA, 1995.

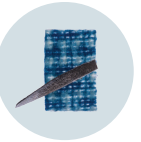
Cf. Sedov, B.B. Finno-Ugri i Balti v Epokhi Srednevekovija, Moscow, 1987



Forging a traditional Japanese sword is an intense process. It begins with smelting iron sands in a massive, purpose-built clay furnace known as a *tatara*. Layers of charcoal and iron sands kept under constant heat for days, by means of a massive bellows, would eventually yield a porous mass of iron, slag, and steel known as a bloom. When complete, the bloom is removed and different grades of steel are separated based on their carbon content. The most famous being *tamahagane* (left), a high-carbon, hardened steel which gets its name from its almost jewel-like appearance.

SPECIMEN TYPE:
HUMAN ARTIFACT

SWORD AGE:
C. EARLY 14TH CENTURY CE



samurai sword

"夏草や 兵どもが 夢の跡 - Summer grass... all that remains of warrior dreams.."

– Matsuo Bashō (1644–1694)

The Japanese sword is a symbol of unparalleled beauty and quality. Bound closely to the image of the samurai class, the blades are highly prized and honored by collectors all over the world. The history of these incredible weapons and the warriors who wielded them are intimately connected to the development of the Japanese nation and the culture of modern Japan.

The oldest blades, known as *Ko-tō* (literally Old Sword) were created by combining *tamahagane* with steel containing both higher and lower amounts of carbon. Kneading or folding this mixture created a material that could be both strong and flexible, provided the blade survived the creation of the ultra hard edge known as the *ha*.

To create the *ha*, the swordsmith would coat the blade with a combination of clay, charcoal, and crushed stone. This mixture was applied in two steps. First a light coat for the entire blade and then a second, thicker coat for the body. Returning to the forge, the blade would be thermal cycled several times. This process of heating and cooling causes the metal to expand and contract, forcing a molecular reorganization which makes the material denser. The varied application of the clay controls the heat allowing the edge to become harder while the spine remains flexible. It also results in a beautiful and natural outline of the hardened area, known as the *hamon*.

This way of manufacturing continued for nearly 400 years until the Edo era at the start of the 17th century.

The Edo era represented a major change for Japanese society. The previous century was

a time of continuous internal conflict. War, famine, and political intrigue among hundreds of local rulers and warlords kept the entire country on edge. Reunified under the Tokugawa clan in 1603, the new shogunate ruled the country from the city of Edo for 265 years, and "the way of the warrior" was transformed into a far reaching philosophy on how to live a moral life.

The strict set of laws which governed the military rule of the Tokugawa shogunate reached into nearly every aspect of public and private life. The rules even dictated the maximum size for both the *Katana* and *Wakizashi* swords and the method of manufacture.

Tamahagane during this era was mass produced using new methods, which resulted in a steel with much higher carbon content. This made the *tamahagane* stronger but also made it difficult to combine with other grades of steel. As a result, the new swords or *Shin-tō* were created using a laminating process which wrapped the harder steel around a softer core. According to polishing experts, older swords were superior in strength and flexibility. This belief led to the cutting down of many longer *Ko-tō* to fit the blades to the new standard.

The specimen in the Mini Museum is comprised of two parts. The first is from a *Ko-tō* period *katana* circa the mid-1300s. It is a single-forged blade attributed to the Yamato Senjuin School crafted in the area which is now Nara, Japan. Core slices from the blade match the 4th example from the left on the facing page.

Originally, a *tachi* with a cutting edge of 80cm, the Yamato Senjuin *katana* is a fine example of an *o-suriage* sword, or a blade that was shortened to meet the standards of the Edo era (70cm cutting edge or 2-*shaku* 3-*sun* using traditional measurements).

The blade was selected with the generous support of Pablo Kuntz. Pablo is the owner of Unique Japan, a respected dealer of Japanese swords worldwide. While lovely, the blade has a number of micro-fractures that made it unsuitable, and potentially dangerous, as a collectible.

The second piece is a late-Edo period *Kataginu* or pleated front vest. The *Kataginu* was selected to compliment the sword and was acquired at auction in 2015.

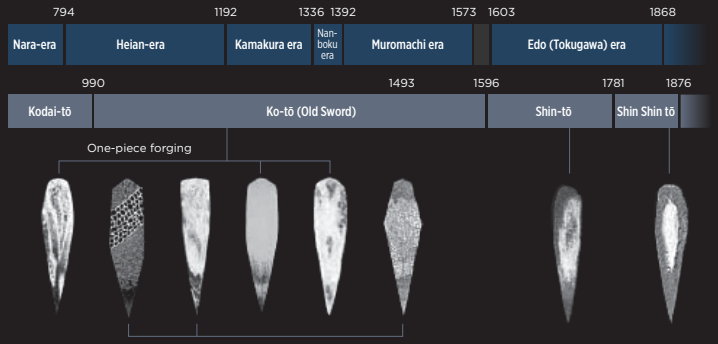
SOURCES:

Nagayama, Kōkan. The Connoisseur's Book of Japanese Swords. Kodansha International, 1997.

Yoshikawa, Eiji. Musashi. Kodansha International, 1995.

Musashi, Miyamoto. The book of five rings. Shambhala Publications, 2005.

Samuari sword core slices through the ages illustrating different forging methods.



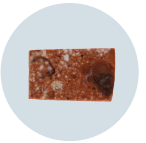
Below: "Having Achieved Their Goal, the Faithful Samurai Withdraw to *Sengoku-ji*" 義士本望を達して仙国寺へ引取図, Utagawa Kuniyoshi (1797-1861)

Over the last millennia, humans have made many changes to combat flooding in the Venice Lagoon, from diverting the flow of rivers to dredging and enhancing the natural sand bars that keep the bay enclosed. Occasionally, the results of human activity have done more harm than good.

Perhaps the most significant damage was done in the 20th century when mainland industries pumped enormous quantities of water from aquifers beneath the lagoon, causing a dramatic subsidence. For several decades, it appeared that this activity may have doomed the city. In recent decades, the government of Italy has worked to develop a system of enormous, mobile gates.

SPECIMEN TYPE: HUMAN ARTIFACT

AGE: C. EARLY 14TH CENTURY CE



venice

(sunken street brick)

"I stood in Venice, on the Bridge of Sighs;
A palace and a prison on each hand..."

– Lord Byron, 1812

The City of Canals, the City of Bridges, the City of Masks... The city of Venice has been known by many names and ruled by many hands. Yet despite its legendary history at the center of a long-lived republic, it is the ever-present Adriatic Sea which has defined the fortunes of Venice, and it is to those waters that the city may eventually return.

The modern city of Venice is situated on one of several islands in a natural lagoon on the northeast coast of Italy. This enclosed bay formed roughly 6,000 years ago as floodwaters from the late Pleistocene sea level rise receded from the coastal plains. The region still experiences severe, natural flooding as peak tides combine with occasional warm winds in a phenomenon known as *acqua alta*.

Founded in 421 CE, the original "city" of Venice was little more than a trading post on the island of Rialto. This was a time of severe decline in the power of the Western Roman Empire. Thirty years later, Attila the Hun swept into the region. As the Empire struggled, the local coastal and island communities around the lagoon came together for mutual protection. They created a loose form of self-government, electing representatives or tribunes to decide broad matters.

In the chaos that followed the final collapse of the Western Roman Empire, the entire region found itself in the center of new conflicts, the greatest of these being the Byzantine conquest of Italy during the Gothic War of 535-554 CE, the Lombard invasion of northern Italy in 568 CE.

Uncovering the early 14th century streets of Venice.

Jacopo de' Barbari's woodcut, *The Map of Venice*, c. 1500

Each successive wave of crisis brought more people to the lagoon. As the population swelled, it became more difficult for the tribunes to effectively govern in a coordinated fashion, so in 697, the position of *Doge* or chief magistrate was established to manage the region.

There is some debate as to whether the first *Doges* were elected by the people or appointed by the Emperor of the Byzantine Empire. Either way, they certainly held enormous power, ruling in an almost autocratic fashion until the establishment of a Great Council or *Consilium Sapientis* and subsequent smaller councils that would ultimately form the complicated structure of the Venetian government.

As the seat of power in the Republic, the city of Venice held great sway over commerce and maritime transport in the region. Many Venetians traveled even further, including the Polo family who went all the way to the court of Kublai Khan in China.

But the Venetians were not alone... They warred with the city of Genoa, their counterpart on the other side of the Italian peninsula, as well as other city-states such as Pisa. While fighting among each other, these maritime republics generally tried to maintain a position of neutrality with larger states upon which they all relied for commerce, though often with less success than they might have liked.

After nearly one hundred years of intermittent conflict, the Venetians prevailed against their rivals in Genoa in 1380. They became the dominant sea power in the Eastern Mediterranean and ruled the Adriatic with a fleet of more than 3,300 ships.

The Republic of Venice remained a powerful state for the next two centuries, but their power waned as global trade routes shifted away from the Mediterranean and towards the Atlantic. According to many scholars, Venice also made a critical error in strategic judgement by becoming more involved in the politics of mainland Italy. These major economic and political stresses were compounded further by two major bouts of the black plague, which killed off nearly 30% of the population.

By the late 18th century, the fortunes of Venice were greatly reduced as the Napoleonic Wars closed in on the Republic from both sides. The navy, once the jewel of the Republic, had dwindled to just 11 ships. Venice could offer no resistance as the Austrian and French armies occupied their mainland territories and subsequently divided the Republic in the April of 1797.

Napoleon famously told Venetian representatives in Graz, "I want no more Inquisition, no more Senate; I shall be an Attila to the state of Venice." Then, a month later he made good on his statement by arriving at the shores of the lagoon to take possession of the city.

Faced with insurmountable forces, the Grand Council voted to surrender. The final Doge of Venice, Ludovico Manin, removed the *corno ducale* from his head and 1,100 years of the *Serenissima Repubblica di Venezia* (The Most Serene Republic of Venice) came to an end.

The specimen in the Mini Museum comes from an early 14th century paving brick uncovered in the *Cannaregio sestiere* during a recent renovation. The brick was acquired directly from the architectural firm performing the renovation. We are extremely grateful for the assistance of Mini Museum Backer N. Lugato in identifying and securing this specimen.

SOURCES:

Strathern, Paul. The Venetians: A New History: From Marco Polo to Casanova. Random House, 2012.

Crowley, Roger. City of fortune: How Venice ruled the seas. Random House, 2012.

Rapaglia, John. "Submarine groundwater discharge into Venice Lagoon, Italy." Estuaries 28.5 (2005): 705-713.

Grygiel, Jakub J. Great powers and geopolitical change. JHU Press, 2006.

Teatini, P., et al. "Anthropogenic Venice uplift by seawater pumping into a heterogeneous aquifer system." Water Resources Research 46.11 (2010).

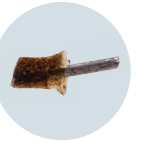
This 1858 illustration depicts the national personification of Brother Jonathan (New England) and John Bull (United Kingdom and England) shaking hands after the connection of the cable.

SPECIMEN TYPE:
HUMAN ARTIFACT

LENGTH:
2500 NAUTICAL MILES

WEIGHT:
5200 TONS

DATE:
1858



first transatlantic cable

"What hath God wrought?"

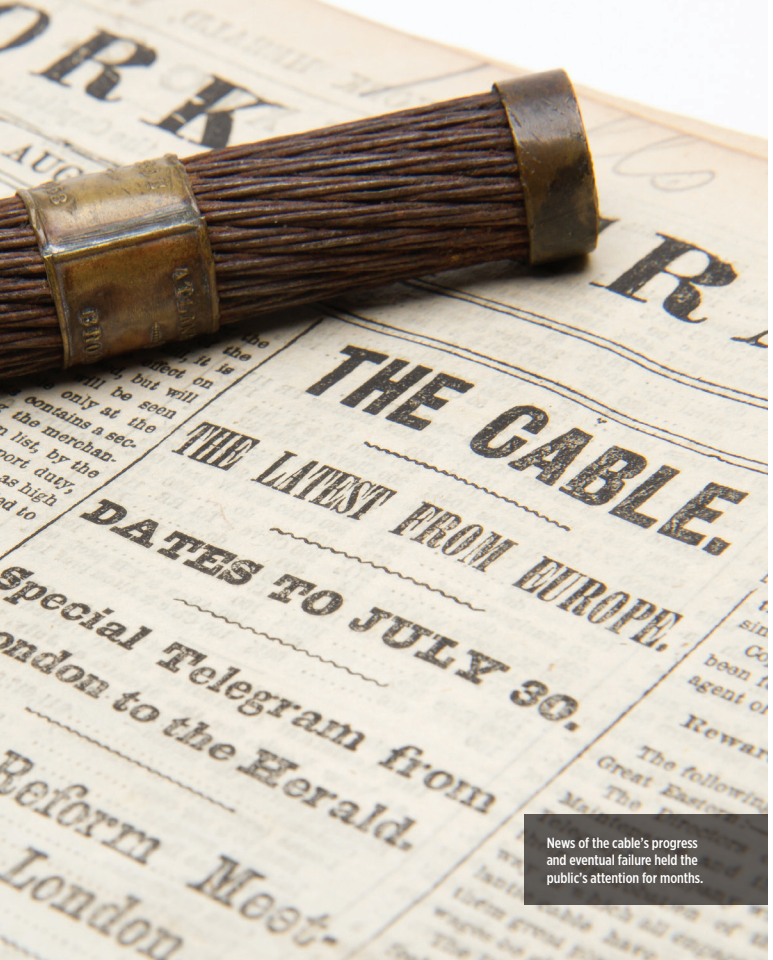
– Samuel F.B. Morse, 1844

Ten years after Samuel F.B. Morse sent the first telegraph message in 1844, the world was hooked on the new form of rapid communication. Transmission lines crossed mountains, rivers, and national boundaries. Even 20 miles of the English Channel could not hold back the constant flow of messages.

Yet even with this breathtaking progress, overcoming the Atlantic Ocean seemed an impossible task. Nearly two thousand miles of open ocean separated the closest two points between Europe and North America, and the depth along the route often exceeded two miles. Spanning this enormous gap would require the will of a person of immense vision and grit, and perhaps even a touch of madness.

Born in 1819, Cyrus West Field was one of eight children. He began an early career in business as a dry goods merchant in New York, leaving to become a paper salesman. Still young, he joined a paper manufacturing partnership, then nearly fell into financial ruin when the business collapsed and he somehow came out personally responsible for the debts of his partners. Not to be held down, Field went out and started a new paper manufacturing business, becoming a primary supplier to the burgeoning penny presses of the day. Field sold his business and found himself incredibly wealthy. He and his brother purchased matching mansions in New York's hottest new private development: Gramercy Square.

But Field was still a young man and he hungered for adventure. Along with a friend, painter Frederic Edwin Church, he travelled to South America following in the footsteps of 18th



News of the cable's progress and eventual failure held the public's attention for months.

century scientist Alexander von Humboldt. Field had Church paint sweeping landscapes and volcanoes to capture the incredible vision left behind by von Humboldt in his book *Cosmos*.

Returning home to New York, Field became very excited by a new technology: the telegraph. Lines for the telegraph were appearing everywhere, but Field had the idea that a line stretching from Europe to America might change the world. Without hesitation he set out to make it happen.

In 1854, Field raised a fund among his wealthy New York friends equivalent to $40M in today's currency to develop the technology needed to draw the cable across over 2,000 miles of ocean. Three years later, the US Government also authorized annual payments of nearly $2M per year to help fund the development.

Then in August 4th, 1858, after already suffering one failed attempt to connect the line, Cyrus Field and the USS Niagara reached Trinity Bay, Newfoundland, connecting the first Transatlantic Telegraph Cable.

"I have no words to express the feelings which fill my heart tonight -- it beats with love and affection for every man, woman, and child who hears me. What God has joined together, let no man put asunder." - Cyrus West Field, 1858

Within days, messages began flowing between the two continents at a rate never before imagined. The world had become smaller in what seemed like an instant.

Charles Tiffany of Tiffany & Co. purchased the remaining cable from Field with the intent of selling souvenirs. However, the wonder of this advancement was not to last, as the cable failed within just a few weeks. Tiffany was unable to sell more than a few of the finished pieces before the world turned against Field with a fury that was just as intense as their initial excitement.

Field was not to be put off. He set back to work immediately, creating a new company. It would be hard work, but ten years later a new, sturdier cable would be set in place. This cable would not fail, and Field would be treated to awards and accolades from across the world.

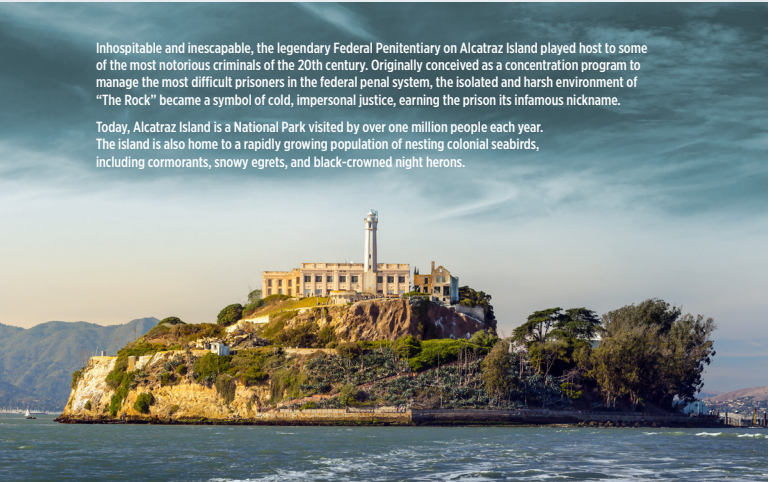
The specimen in the Mini Museum comes from a section of the original Transatlantic cable carried aboard the U.S.S. Niagara. After the completion of the first line, the remaining cable was purchased by Charles Tiffany with the intent of selling souvenirs commemorating the linking of both continents. However, when the first cable failed a few weeks later, Tiffany & Co. was unable to sell the remaining cable and put it into storage. Over 100 years later, several cases of finished cable sections were located and later sold by the Smithsonian Institution.

SOURCES:

Standage, Tom. The Victorian Internet: The remarkable story of the telegraph and the nineteenth century's online pioneers. London: Weidenfeld & Nicolson, 1998.

Hearn, Chester G. Circuits in the sea: the men, the ships, and the Atlantic cable. Greenwood Publishing Group, 2004.

Nathan, Adele Gutman. The First Transtlantic Cable. 1959.

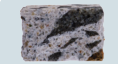


Inhospitable and inescapable, the legendary Federal Penitentiary on Alcatraz Island played host to some of the most notorious criminals of the 20th century. Originally conceived as a concentration program to manage the most difficult prisoners in the federal penal system, the isolated and harsh environment of "The Rock" became a symbol of cold, impersonal justice, earning the prison its infamous nickname.

Today, Alcatraz Island is a National Park visited by over one million people each year. The island is also home to a rapidly growing population of nesting colonial seabirds, including cormorants, snowy egrets, and black-crowned night herons.

SPECIMEN TYPE:
HUMAN ARTIFACT

TOTAL PRISONERS OVER 29 YEARS OF OPERATION:
1,545



alcatraz

"It looks like Alcatraz has got me licked."

– Gangster Al Capone

When Spanish naval officer Juan Manuel de Ayala y Aranza passed through the Golden Gate in August of 1775, he became the first European to sail into the San Francisco Bay. Seemingly free of the crippling fogs so common down the coast in Monterey, Ayala felt the bay would make an ideal harbor. He spent a little more than a month in the bay, charting the features and making contact with local Native American tribes. He gave names to many features, including a sandstone island so densely populated with brown pelicans he named it *La Isla de los Alcatraces*, a name which stuck when the United States took possession of the island in 1846.

The island remained barren for many decades until gold was struck in the Sierra Nevada.

Fearing that foreign interests might try to take control of the suddenly valuable region, President Millard Fillmore signed an order in 1850 placing Alcatraz Island, as well as several others in the bay, under the control of the U.S. Army and directing the construction of defensive fortifications.

While the gun batteries of Alcatraz fortress were never called upon to defend the city, the remote nature of Alcatraz made it an ideal location for holding military prisoners. Confederate soldiers and sympathizers were housed here during and after the Civil War, as were so-called "rebellious" Native Americans. During the Spanish-American War, the incarcerated population of Alcatraz soared into the hundreds, leading to more construction.

After a fire destroyed the wooden citadel, construction began on what would become the world's largest reinforced concrete building.

Completed in 1912, this 600 cell structure would house conscientious objectors during World War I and eventually become the foundation for the U.S. Federal Penitentiary known as "The Rock."

In all, some 1,545 men were incarcerated at Alcatraz, including famous Chicago gangster Al Capone, James "Whitey" Bulger, George "Machine Gun" Kelly, and Robert Stroud, also known as "The Birdman of Alcatraz." Over the course of 29 years, only 36 inmates attempted to escape Alcatraz. Officially there were no successful escapes, however, in the early hours of June 12th, 1962, Frank Morris and brothers Charles and John Anglin slipped into the San Francisco Bay in a makeshift raft crafted from stolen raincoats.

The trio worked for six months to widen the ventilation ducts inside their cells and then escaped through a utility corridor behind their cellblock. Fragments of their personal belongings as well as the remains of their raft were discovered but the prisoners bodies were never recovered.

Ironically, the men were aided in part by the very construction which set Alcatraz apart when it was completed in 1912. Back then, Alcatraz was a military prison and the new cellblock was the largest reinforced concrete building in the world. After decades of exposure to the salty, cold winds of the San Francisco Bay, airborne chlorides penetrated the concrete and degraded the reinforcing steel. This was further exacerbated by the atmospheric carbon dioxide which had carbonated the concrete and caused further corrosion.

Less than a year after the 1962 escape, Attorney General Robert F. Kennedy ordered the prison closed.

After the Federal Penitentiary closed, Alcatraz was abandoned and declared surplus property by the U.S. Government. Native American rights activists made several claims for the island based on the 1868 Treaty of Fort Laramie. A symbolic occupation of Alcatraz occurred during 1964 and then later in 1969 after a second occupation, a group of 89 people set out for Alcatraz with the intention of laying claim to the island. After landing a small party, a proclamation was issued by The Indians of All Nations, claiming the island by right of discovery, and signing off with the famous cry of, "We Hold the Rock!"

For over a year, activists held the island with the population peaking at over 400 people. This successful occupation was linked to many Native Rights protests during the 1970s and remains the inspiration for the annual Indigenous Peoples Sunrise Ceremony (or Unthanksgiving Day) held each year on Alcatraz Island with the full support of the National Parks Service.

This rallying point also speaks to the deeper history of the island. According to native histories, the island was actually a place of exile in ancient times and served as a place of refuge when the first Spanish came to the area.

The actual bedrock of the 22-acre Alcatraz Island is called greywacke. This sandstone melange was laid during the Cretaceous and is part of a geologic terrane which includes most of the City of San Francisco including Nob, Russian, and Telegraph Hills. During the Pleistocene Epoch, the San Francisco Bay was free of water and what is now the Sacramento River ran through the Golden Gate to the sea (*see geological terrane map below*). The course of this river can still be traced on the floor of the bay as it winds around Alcatraz and nearby Angel Island.

According to paleoclimate studies, the bay underwent several warming and drying cycles from the beginning of the Holocene some 10,000 years ago until roughly 4,000 years ago when the bay was inundated with rising seas and assumed its current state.

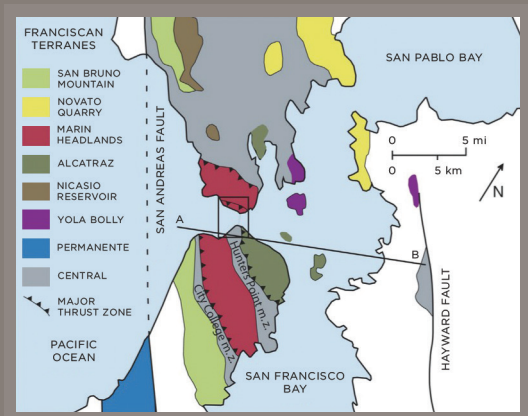
The specimen in the Mini Museum comes from material salvaged by the National Park Service during restoration of what was once the world's largest reinforced concrete structure.

SOURCES:

Johnston, James A. Alcatraz Island prison and the men who live there. Read Books Ltd, 2013.

Saenz, BENJAMIN L., et al. "An urban success story: breeding seabirds on Alcatraz Island, California, 1990–2002." Marine Ornithology 34.1 (2006): 43-49.

Elder, William P. "Geology of the Golden Gate headlands." Geology and Natural History of the San Francisco Bay Area: A Field-trip Guidebook. US Geological Survey Bulletin 2188 (2001).



Home of the Codebreakers: Bletchley Park in Milton Keynes, Buckinghamshire, England where Alan Turing and the Government Code and Cypher School cracked the Enigma and developed the "Ultra" intelligence used to shorten the War.

SPECIMEN TYPE:
HUMAN ARTIFACT

MAXIMUM PERMUTATIONS:
1.56 X 10^{25} OR 84 BITS

WWII enigma
(rotor)

"The German U-boats were sinking our food ships and our ships bringing in armaments left right and centre, and there was nothing to stop this until Alan Turing managed to break naval Enigma, as used by the U-boats. We then knew where the U-boats were positioned in the Atlantic and our convoys could avoid them. If that hadn't happened, it is entirely possible, even probable, that Britain would have been starved and would have lost the war."

– Captain Raymond C. "Jerry" Roberts, Bletchley Park Codebreaker

In times of war, the struggle for information often means the difference between winning and losing. Yet few efforts to conceal and reveal information reached the scale or importance of the puzzle which surrounded the Enigma during World War II.

Not much larger than an average portable typewriter, the German Enigma brand of rotary cipher machines enabled users to easily code and decode messages. Like an electric typewriter, a key press would result in a signal for a certain character. However, instead of triggering electromechanical printing, a light would illuminate on the case showing that letter. By means of a series of interlocking, movable drums the user could scramble the original signal, causing a different light to illuminate.

While relatively complex, mathematicians working for the Polish Cipher Bureau (Biuro Szyfrów) were able to work out the theory behind the early Enigmas as they underwent testing by the German Army in 1932. Using this knowledge, they developed paper keys known as "Zygalski sheets" which helped limit the number of possible starting positions.

During the build up for World War II, the Germans improved the machine and their protocols, making it far more difficult to decode messages. The Poles turned to the allies for help, passing on their knowledge

Left: Macro image of manufacturing marks on the thumbwheel.

Right: Restored Engima with plugboard exposed.

shortly before the German invasion of Poland. This help was essential to understanding the basic framework and sped development of ways to counter the increasing complexity the Germans introduced to the Enigma platform.

To solve this problem, Britain turned to a group of academics to develop a completely new type of technology. Installed at Bletchley Park, these brilliant women and men introduced a series of electro-mechanical devices called "Bombes" designed to simulate dozens of Enigma machines so that possible configurations could be tested and eliminated. While the war of encryption went on, the allies managed to stay up to date with each advance, even developing the first true programmable computers. The knowledge gained by their tireless efforts changed the course of the war, and their achievements led to the first steps of the information age.

The specimen in the Mini Museum comes from the remains of several ruined, military-grade Enigma rotors. Each individual specimen contains fragments from the key components of the rotor, including: the notched "thumbwheel," the alphabet ring, and the core of the rotor which contained the wiring and contacts that enabled the system to function.

SOURCES:

Hodges, Andrew. Alan Turing: the enigma. Random House, 2012.

McKay, Sinclair. The Secret Lives of Codebreakers: The Men and Women who Cracked the Enigma Code at Bletchley Park. Penguin, 2012.

Hamer, David H. "Enigma: Actions Involved in the 'Double Stepping'of the Middle Rotor." Cryptologia 21.1 (1997): 47-50.

Kruh, Louis, and Cipher Deavours. "The commercial enigma: beginnings of machine cryptography." Cryptologia 26.1 (2002): 1-16.

The first SR-71 flight took place on December 22, 1964. Though many mission records about the Blackbird have been declassified, the full extent of the Blackbird's operations is unknown. What is known is that in 35 years not a single SR-71 was lost to hostile actions. For enemy fighters, the aircraft was simply too fast and flew too high. For surface to air missiles, the radar signature of the SR-71 was too small to be detected until it was too late to react.

SPECIMEN TYPE:
HUMAN ARTIFACT

TOP PUBLISHED SPEED:
1,905.81 KNOTS (2,193.2 MPH; 3,529.6 KM/H), APPROXIMATELY MACH 3.3

TOP ACKNOWLEDGED ALTITUDE:
85,069 FT (25,929 M)

SR-71
(blackbird)

"Nothing had prepared me to fly that fast...
My God, even now, I get goose bumps remembering."

– Air Force Colonel Jim Wadkins

The SR-71 was built for speed and stealth. Setting records as the world's fastest manned aircraft, the SR-71 easily cruised at more than three time the speed of sound. The spy plane was also the highest-flying manned aircraft, soaring to over 85K feet (26K meters). Development of this incredible aircraft required rethinking every aspect of aeronautical design. In fact, an entire industry grew up around the program as nearly every component was custom made, from the titanium alloy skin to the fuel the huge engines consumed.

The Blackbird program got off the ground in 1957 when the US Central Intelligence Agency commissioned the development of an undetectable aircraft capable of high altitude, high speed reconnaissance. The agency turned to Lockheed's "Skunk Works" operation and aeronautical engineering legend Clarence Leonard "Kelly" Johnson.

For decades, Johnson helped develop some of the most important aircraft in US Air Force history, including such diverse craft as the P-38 Lightning and the U-2 Spy Plane. The Blackbird would be Johnson's penultimate aircraft, surpassing all previous engineering efforts and establishing a technology platform that still holds every record it set, even more than 50 years after its maiden flight.

The first official Blackbird test flight occurred on April 30th, 1962. This model, the A-12, was a smaller, single seat version of what would become the SR-71. The test took place at the secretive Groom Lake, Nevada Air Force base also known as Area-51, Dreamland, or

In the cockpit: USAF SR-71 pilot (Major Brian Shul, Ret.) in full flight suit.

Birds of a Feather: Visiting the SR-71 at the National Air and Space Museum Steven F. Udvar-Hazy Center. Kind thanks to Layne Karafantis, PhD. and Curator of Modern Military Aircraft.

simply "The Ranch." Legendary names all used to describe the highly sensitive United States Air Force facility built around the dry, Nevada lake bed of Groom Lake. Like the U-2, the A-12 and the SR-71 underwent testing here far from prying eyes. Over the years, the site has been the source of many rumors, but what is known is that this remote airbase has played host to the most advanced aircraft ever designed.

For those lucky few who were able to fly the SR-71, the experience turned out to be something also quasi-religious. That sense of reverence also extended to those who faced the SR-71 as an enemy aircraft. Viktor Belenko, the soviet MiG pilot who defected to Japan in 1976 wrote, "They taunted and toyed with the MiG-25s sent up to intercept them, scooting up to altitudes we could not reach, and circling leisurely above them or dashing off at speeds we could not match."

In 1989, despite the continued superiority of the platform, the SR-71 program was slated for retirement. It's generally believed that politics were at the root of the retirement since the SR-71 remained the fastest plane in the sky by a wide margin and its reconnaissance capabilities were still needed. For nearly a decade, opponents and proponents of the SR-71 wrestled with the issue, reactivating the program in the mid-90s and then permanently retiring the craft in 1998. The final SR-71 mission occurred on October 9th, 1999.

Officially, there is no known replacement for the SR-71, though most capabilities have been replaced by satellites and unmanned aerial vehicles (UAV).

The specimen in the Mini Museum is a fragment of a "turkey feather" from SR-71 61-7972. It was purchased from Daniel Freeman, Supervisor and Chief of Metals Technology for the 9th Reconnaissance Wing I.

The turkey feathers are overlapping flaps which surrounded the exhaust of the SR-71. Opening and closing according to the pressure output of the afterburner, they are considered one of the hardest working parts of the aircraft. SR-71 61-7972 was retired in 1990 and is currently on display in the Smithsonian's Air & Space collection at the Udvar-Hazy Center just outside Washington, D.C. During the delivery flight from Los Angeles, the aircraft flew coast to coast in just 67 minutes.

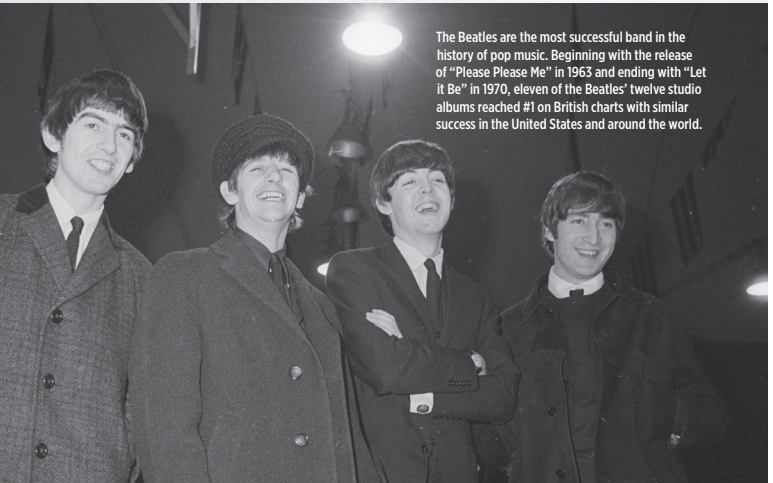
SOURCES:

Graham, Richard. The Complete Book of the SR-71 Blackbird: The Illustrated Profile of Every Aircraft, Crew, and Breakthrough of the World's Fastest Stealth Jet. Zenith Press, 2015.

Maglieri, Domenic J., Vera Huckel, and Herbert R. Henderson. "Sonic-boom measurements for SR-71 aircraft operating at Mach numbers to 3.0 and altitudes to 24384 meters." (1972).

Miles, Richard B., et al. "Suppression of sonic boom by dynamic off-body energy addition and shape optimization." AIAA Paper 150.2002 (2002): 33.

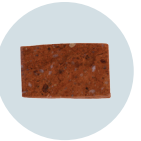
Boyer, R. R., and R. D. Briggs. "The use of ß titanium alloys in the aerospace industry." Journal of Materials Engineering and Performance 14.6 (2005): 681-685.



The Beatles are the most successful band in the history of pop music. Beginning with the release of "Please Please Me" in 1963 and ending with "Let it Be" in 1970, eleven of the Beatles' twelve studio albums reached #1 on British charts with similar success in the United States and around the world.

SPECIMEN TYPE: HUMAN ARTIFACT

TOTAL PERFORMANCES: 292



the beatles
(cavern club)

"The Cavern... Do I have memories of the Cavern? Do I? Oh yeah."
– Sir Paul McCartney

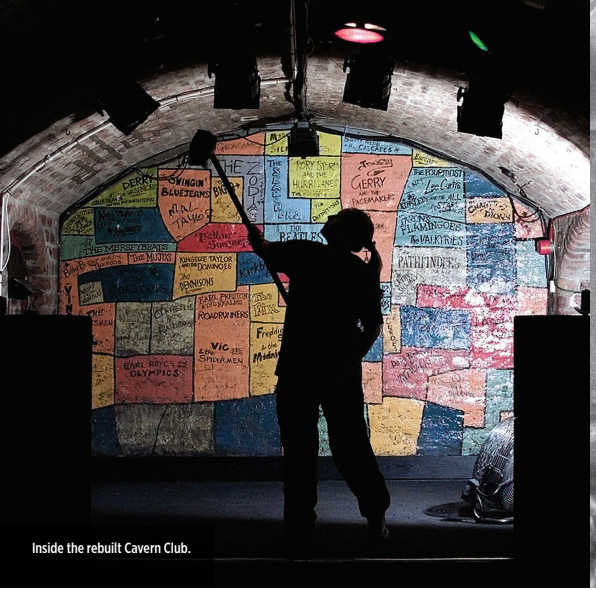
Before The Beatles played for millions of viewers on The Ed Sullivan Show, the Lads from Liverpool put in thousands of hours in clubs and lounges across the UK, Germany, Sweden, and France. Yet few venues can be so closely associated with earliest days of the Beatles as the original Cavern Club in Liverpool, England.

According to the archives of the Cavern Club, The Beatles first played the Cavern Club in 1961, but it wasn't John Lennon and Paul McCartney's first time in the basement of the former fruit warehouse. They'd played the club before as The Quarrymen in 1957 when the club was strictly a jazz venue.

Sir Paul McCartney recalled that first gig in Spenser Leigh's book, *The Cavern Club: The Rise of The Beatles and Merseybeat*:

"We fibbed about our repertoire and managed to get a date there, where we proceeded to announce songs like 'Long Tall Sally' as written by Blind Lemon Jefferson and 'Blue Suede Shoes,' the famous creation of the legendary blues artist Leadbelly! When the owners of the Cavern realized what we were doing, then sent little notes up to the stage complaining but it was too late."

Four years later much had changed. The Beatles had picked up George Harrison (1958) and drummer Peter Best (1960). They'd also been playing a new kind of music, a rock-and-roll offshoot called "beat," which was sweeping over the UK and the club scene in Hamburg, Germany. The new ownership of the Cavern Club had also embraced beat music and the throngs of



Inside the rebuilt Cavern Club.

George Harrison, Paul McCartney and John Lennon during the final performance at the Cavern Club

screaming teenage girls that seemed to follow their favorite bands everywhere they went.

From 1961 to 1963, the Fab Four played 292 shows in the Cavern Club. This is where they first met manager Brian Epstein, who came to nearly all of their shows for three weeks straight. It was also the location of their famous 1962 Welcome Home concert when the band returned from their final residency in Hamburg, and the frenzy that would become Beatlemania was first put on display. Ringo Starr also made his public debut here with the band just two months later, and before the year was out the group shared the stage with the legendary Little Richard.

On August 3, 1963, just a month after recording "She Loves Me," the Beatles played their final performance at the Cavern Club. Six months later the Beatles rocketed to stardom while the Cavern Club played host to other legendary bands such as The Rolling Stones, The Yardbirds, Elton John, the Kinks, Queen, and The Who.

Later, the beat wave came to a close, and the Cavern Club fell on hard times. The club was demolished in 1973, but the bricks were saved. In 1983, a selection were auctioned for charity and the remaining bricks were used in the rebuilding of the Cavern Club on the original site. The specimen in the Mini Museum comes from one of the original bricks, purchased at auction in 2016.

In 2015, Sir Paul McCartney said of the Cavern Club, "It was the breeding ground for what would become the Beatles' early repertoire, and I will always think of the place with great affection for the days spent with my pals in its sweaty, damp atmosphere."

SOURCES:

Thompson, Phil. The Best of Cellars: The Story of the Cavern Club. Tempus, 2007.

Kruse, Robert J. "The Beatles as place makers: Narrated landscapes in Liverpool, England." Journal of Cultural Geography 22.2 (2005): 87-114.

Braun, Michael. Love me do: the Beatles' progress. Penguin, 1964.

SPECIMEN TYPE:
HUMAN ARTIFACT

ALSO KNOWN AS:
MOTOR AGATE, DETROIT AGATE

fordite

"Any customer can have a car painted any colour that he wants as long as it is black."

– Henry Ford, 1909

The bright, jewel-like layers of Fordite are comprised of thousands of layers of automobile paint. Drop by drop, each layer represents a different vehicle as it passed through the paint booth in the factory. Heated to hundreds of degrees, the layers fused together to form one of the most beautiful and completely accidental man-made composites.

Beautiful to look at, Fordite also provides a look into the history of automobile manufacturing.

The earliest cars were painted by hand, often using brushes or by dipping parts in slow-drying varnishes. By some accounts it took days to dry car bodies, and manufacturers like Henry Ford took to pre-making thousands of car bodies in advance and storing them on floors built above the assembly line.

By the 1920s, advances in paint technology allowed the industry to move to spray guns and faster drying nitrocellulose lacquers. It was during this time that most cars began undergoing heat treatment to bond the lacquer to the metal and to help the paint dry even faster.

Fordite first made its appearance in the 1940s. As thousands of vehicles moved more quickly through each factory, dripping paint from overspray built up on the rails and eventually had to be chipped away. The colors of the time were darker and more muted, but the swirling patterns were all there. Later, during the 1950's and 1960's when acrylic lacquers had taken over, Fordite appeared in bright metallic colors.

While the "Detroit Agate" version of Fordite is a more modern invention, Fordite was for a time an actual product of the Ford Motor Company. Henry Ford (pictured) had a habit of recycling and reusing as much material as possible. By combining rubber, silica, sulphur, and straw from Henry Ford's farm, the company created a composite material used in the manufacturing of steering wheels.

In the 1970's, auto manufacturers began moving to electrostatic bonding of paint to cut down on waste and to reduce the environmental impact of volatile organic compounds. The introduction of industrial paint robots also cut down on the amount of Fordite produced by the automotive industry, but, despite rumors to the contrary, "new" Fordite can still be found.

Today, over 90,000,000 cars and trucks are produced around the world each and every year. That's more than 170 vehicles a minute. Two cars were produced while you read the last two sentences. And no matter where on Earth they are assembled, each and every one needs to be painted.

The specimen in the Mini Museum comes from the Ford Kansas City Assembly Plant in Claycomo, Missouri. The plant opened in 1951 and since 1957 the 4,700,000-square-foot (440,000 m^2) facility has been home to ten generations of F-Series Pickup Truck production, as well as many others including Falcon, Comet, Fairlane, Meteor, Maverick, Fairmont, Zephyr, Tempo, Topaz, Contour, Mystique, Light Trucks, Flareside Trucks, Lincoln Blackwood Truck, and the F-150 Harley Davidson SuperCrew.

SOURCES:

Ford, Henry, and Samuel Crowther. My life and work: In collaboration with Samuel Crowther. Cornstalk Publishing Company, 1922.

Geffen, Charlette A., and Sandra Rothenberg. "Suppliers and environmental innovation: the automotive paint process." International Journal of Operations & Production Management 20.2 (2000): 166-186.

The Many Layers of Fordite: Each layer represents a different vehicle on the assembly line.

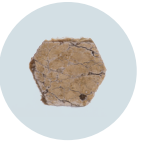
Entering late in group play, Pelé stole the world's heart with his energetic and sometimes outrageous style of play. In the semi-final against France, Pelé scored three goals. Then in the final against host country Sweden, Pelé scored two goals in the second half, helping to bring home Brazil's very first World Cup trophy.

SPECIMEN TYPE:
HUMAN ARTIFACT

WORLD CUP MATCHES:
91

WORLD CUP GOALS:
77

WORLD CUP MATCHES:
1958, 1962, 1970



Pelé

(soccer ball)

"I close my eyes, and I can still see my first soccer ball."

– Pelé

Like many Brazilians, Edson Arantes do Nascimento has been known by many names. He was called "Dico" by his family and "Gasolina" because he was so fast, but the one name that really stuck was Pelé. The name Pelé has no actual meaning in Portuguese, but the life of the greatest soccer player of all time has been anything but meaningless.

Born on October 23rd, 1940 in the city of Bauru in the state of São Paulo, Brazil, Pelé grew up very poor, but loved by his family. His father, João Ramos do Nascimento, also known as "Dondinho," was a gifted soccer player in his own right but his career prospects were cut short by an early knee injury from which he never fully recovered. Dondinho never lost his love of the game though and he worked hard to train his son and shape the young boy's natural talent.

Pelé rose quickly, joining the professional football club Santos at age 15 and scoring a goal in his very first game off the bench. At just 17, Pelé was called up to the National Team, and he was introduced to the world at the 1958 World Cup in Sweden.

Following this incredible early success, Pelé went on to score 1,283 career goals and played on two more winning World Cup teams (1962, 1970). Those who met him on the field used words like "flawless" and "magical," sowing seeds for the legend that would lead to yet another nickname - "The King."

Since retiring from play, Pelé has travelled the world promoting soccer and serving as an inspiration for million of people. His lasting legacy is one of peace and sportsmanship.

To give some sense of his impact it seems fitting to share the words of Nelson Mandela who presented Pelé with the very first Laureus World Sports lifetime achievement award:

> *Peace is the greatest weapon mankind has to resolve even the most intractable difficulties. But to be an effective agent for peace, you have to seek not only to change the community and the world. What is more difficult is to change yourself before you seek to change others. Only those who have the courage to change themselves and to know that in all communities without exception there are good men and women who want to serve their communities.*

In regards to the peaceful resolution of their problems and it is absolutely essential for the leaders of the community and the world to create an atmosphere where those good men and women can show their maximum abilities in trying to resolve problems in a peaceful manner and that is why a legend like Pele and all of these behind me are our heroes, our hope because what ever they do in their respective fields they are promoting peace. These are monarchs, they are queens and kings, not as a result of heredity, but as a result of their personal commitment and efforts.

> *To watch him play was to watch the delight of a child combined with the extraordinary grace of a man in full.*

Yet, despite climbing to such heights in the eyes of the world, Pelé has tried to maintain a sense of self and humility as a human being. He's often described "being Pelé" almost as if the man on the field were someone else entirely. He looks back fondly on his earliest days as Edson, the boy who shined shoes to help raise money for his family and played with a ball that was "really just a bunch of socks tied together."

The specimen in the Mini Museum comes from a vintage leather football owned by Pelé and acquired by auction in London, England in 2016. This personal auction was the most lucrative sale of football memorabilia in history.

SOURCES:

Winter, Brian. Pelé. Why Soccer Matters. New York: Penguin. 2014.

Fish, Robert L. My life and the beautiful game: The autobiography of Pelé. Skyhorse Publishing Inc. 2007.

Goldblatt, David. The ball is round: A global history of soccer. Penguin, 2008.

South African President Nelson Mandela and Pelé in 1995.

At the 1970 World Cup in Mexico.

Lady Diana Spencer, soon to become the Princess of Wales, showing her wedding gown for the first time, turns as her bridesmaids set her train on arrival at Saint Paul's Cathedral for her wedding to Prince Charles in London, July 29, 1981.

SPECIMEN TYPE:
HUMAN ARTIFACT

MARRIED:
JULY 29TH, 1981

DIVORCED:
AUGUST 28TH, 1996

Charles & Diana

(royal wedding cake)

"Only do what your heart tells you."

– Princess Diana

The marriage of HRH Charles Windsor, Prince of Wales, and Lady Diana Spencer was an international sensation. Watched by an estimated 750,000,000 people around the world, the wedding was the culmination of a fairy tale in which an assistant kindergarten teacher became a Princess overnight.

Yet what seemed to the world like a beautiful story would become much more complicated as the years passed. Despite the birth of their two sons, Princes William and Henry ("Harry"), intense media pressure and infidelity drove the couple apart. Charles and Diana divorced on August 28th, 1996. Just one year later, on August 31st, 1997, Lady Diana died in a car crash while fleeing the paparazzi in Paris. She was just 36 years-old.

On September 6th, 1997, a global audience of more than 2,500,000,000 people watched the funeral held at Westminster Abbey. Diana's brother Charles, the 9th Earl Spencer, gave a very emotional speech, the heart of which might be summed up in this quote:

"Diana was the very essence of compassion, of duty, of style, of beauty. All over the world she was a symbol of selfless humanity. All over the world, a standard bearer for the rights of the truly downtrodden, a very British girl who transcended nationality. Someone with a natural nobility who was classless and who proved in the last year that she needed no royal title to continue to generate her particular brand of magic."

Princess Diana in Hong Kong (1989) wearing a pearl and diamond tiara, which was a wedding gift from the Queen.

In the years since Diana's passing, there have been many books written about the relationship between the Prince and Lady Diana as well as their own private lives as individuals. Given the myriad interests which swirl around the royal family, it is difficult to parse the truth from the opinion. However, what is clear is that Charles and Diana tried very hard to raise a family in the midst of singular pressures only they could truly understand. The heart of their story speaks to the struggles we each face as human beings as we move through our own lives.

The specimen in the Mini Museum comes from a slice of the royal wedding cake, a traditional fruit cake. The layers of the official cake took 14 weeks to prepare, including an identical twin held in emergency reserve. For display, each cake was sliced and placed into individual monogrammed boxes. These prepared slices were then placed into larger, hand-painted boxes and finished with sugar paste icing to form the decorated layers of the cake.

SOURCES:

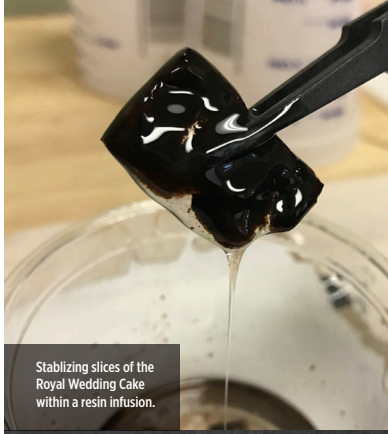
Morton, Andrew. Diana: Her true story in her own words. Simon and Schuster, 2009.

Mayer, Catherine. Born to Be King: Prince Charles on Planet Windsor. Henry Holt and Company, 2015.

McGrady, Darren. Eating Royally: Recipes and Remembrances from a Palace Kitchen. Harper Collins, 2007.

Charles, H. R. H. "Prince of Wales." Juniper and I. Skelly,"Harmony: A New Way of Looking at Our World," Harper Collins Publishers, New York (2010).

Roberts, Andrew, and Antonia Fraser. The House of Windsor. Vol. 6. Univ of California Press, 2000.



Stablizing slices of the Royal Wedding Cake within a resin infusion.

SPECIMEN TYPE:
HUMAN ARTIFACT

BORN:
FEBRUARY 24TH, 1955

DECEASED:
OCTOBER 5TH, 2011

Steve Jobs
(turtleneck)

"I want to put a ding in the universe."

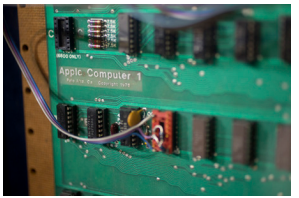
– Steve Jobs

This picture was taken at the 1991 PC Forum gathering where Steve was promoting NeXT. In many ways, NeXT represented the focal turning point for Steve's career.

While the company never managed to deliver the expected sales of its innovative hardware, their software products became very influential. This success led Apple to purchase NeXT, and ultimately brought Steve back to the helm at Apple.

Beginning life as the adopted son of working-class parents, Steven Paul Jobs rose to the height of global business. His companies revolutionized several different industries and his countercultural vision reshaped much of the modern technological world.

Steve Jobs is most famous for founding Apple with his business partner and engineering wizard Steve Wozniak. In April of 1976, the two Steve's (just 21 and 26 years old), and electronics journeyman Ronald Wayne, launched the company. Their first product, the Apple-1, was just a raw motherboard.



Even though this first product was rough, the promise of the Apple-1 was not in the business of making and selling components, but rather in the concept of a personal computer that could be purchased by millions. This concept was realized with the introduction of the Apple][, which went on to carve out a place near the top of the young, personal computer industry.

Steve Jobs delivers the keynote address at the Worldwide Developers Conference June 23, 2003 in San Francisco.

As with any long-lived company in a fast moving industry, the history of Apple is very complex. Steve himself said that he was very fortunate to come of age at a time when the computer industry was very young:

> ***"There weren't many degrees offered in computer science, so people in computers were brilliant people from mathematics, physics, music, zoology, whatever. They loved it, and no one was really in it for the money..."***

Early competitors like Tandy, Atari, and Commodore were replaced with the monolithic IBM. Apple itself went through a major transition as it developed adaptations of XEROX PARC's graphical interface for the Lisa, and later, the Macintosh.

In 1985, Steve was ousted by the board of Apple as the head of the Macintosh group, effectively firing him from the company. Steve put it this way, "What had been the focus of my entire adult life was gone, and it was devastating. I was a very public failure."

After a summer of intense soul-searching, Steve decided to start a new computer company called NeXT. NeXT would consume much of Steve's energy over the next decade, but he did find time to speculate in the field of computer animation after purchasing a division of Lucasfilm in order to form a new company called Pixar.

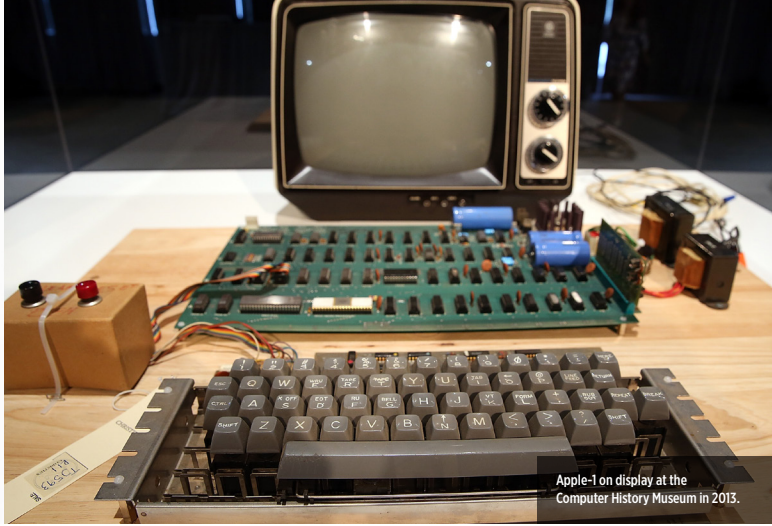
Pixar was headed by visionary computer animation pioneer Ed Catmull. During the company's early years they developed high-performance computer graphics equipment and software. They also produced short animations, winning an Academy Award in 1989 for *Tin Toy*. This creative work led to an opportunity to produce the first feature length, computer animated film called *Toy Story*.

More than just a milestone in computer animation, *Toy Story* would become the highest grossing film of 1995. Steve used the success of the film to drive a wildly successful and bold public offering of Pixar, instantly becoming a billionaire.

This stunning success was followed by Steve's surprising return to Apple a year later. Apple had fallen far behind its rivals and efforts to update its flagship operating system had stalled. To reinvigorate the company, the board agreed to purchase NeXT in a bid to incorporate their technology and staff into the next generation of Apple. The move brought Steve onto the board of directors and a year later he would return to the helm of the company as CEO.

At the time, Apple's fortunes were much reduced, but Steve managed to turn the company around by changing the entire focus of the business from a niche computer company to a consumer electronics leader. This wasn't an easy process, nor was it particularly quick, but it began with the launch of the iPod music player in 2001. By 2004, the iPod was introduced to the world of Windows which opened an enormous market for Apple. Licensing deals in the world of music, and later publishing, film, and television, brought content to the iPod and set the stage for what would become the most profitable product in history: the iPhone.

Steve liked to push up his sleeves so it was no surprise to find the ends of both sleeves so precisely cut.



Apple-1 on display at the Computer History Museum in 2013.

The iPhone launched in 2007, selling roughly 1.4 million units. In the following years, the company would sell tens of millions, then hundreds of millions of iPhones. On July 27th, 2016, Apple marked its one billionth iPhone sale. This extremely profitable product has established Apple as the most valuable company in the world.

Yet, in the midst of this stunning turnaround, human frailty caught up with Steve. In 2004 he was diagnosed with a rare form of pancreatic cancer. Steve would battle on and off with the disease until his death in 2011, often downplaying the effects or blaming his appearance on other illnesses so that he could continue to lead Apple and achieve his vision for the company.

> ***"I think one of the things that really separates us from the high primates is that we're tool builders. I read a study that measured the efficiency of locomotion for various species on the planet. The condor used the least energy to move a kilometer. And, humans came in with a rather unimpressive showing, about a third of the way down the list. It was not too proud a showing for the crown of creation. So, that didn't look so good. But, then somebody at Scientific American had the insight to test the efficiency of locomotion for a man on a bicycle. And, a man on a bicycle, a human on a bicycle, blew the condor away, completely off the top of the charts.***
>
> ***And that's what a computer is to me. What a computer is to me is it's the most remarkable tool that we've ever come up with, and it's the equivalent of a bicycle for our minds." – Steve Jobs, 1995***

The specimen in the Mini Museum is a swatch of fabric from a black mock turtleneck owned by Steve Jobs. One of the earliest examples of what would eventually become Steve's trademark style, this turtleneck was worn by Steve at the 1991 PC Forum gathering. The turtleneck was sold by his personal assistant and purchased at a public auction.

SOURCES:

Isaacson, Walter, and Steve Jobs. "Steve Jobs: A Biography" New York (2011)

Catmull, Ed. Creativity, Inc.: Overcoming the unseen forces that stand in the way of true inspiration. Random House, 2014.

Brennan, Chrisann. The Bite in the Apple: A Memoir of My Life with Steve Jobs. Macmillan, 2013.

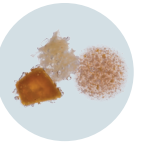
Mir represented the next evolution in a long line of Soviet space stations beginning with Salyut 1 in 1971 and ending with Salyut 7's demise in 1991.

Like the previous space stations, Mir provided a platform for a wide range of experimentation focused on the permanent human habitation of space. The long-term success of Mir speaks to the reliability of the technology developed during the Salyut program, which is still at work today serving as the life-support core of the current International Space Station (ISS).

SPECIMEN TYPE:
HUMAN ARTIFACT

LAUNCH:
FEBRUARY 20TH, 1986

REENTRY:
MARCH 23RD, 2001



Mir

(mission flown food)

"Looking into the station I could see a lone ray of light shining through the port widow and outlining the dining table. We had left some food out for dinner. It was the only time during my stay in space that Mir looked warm, inviting, and spacious. It reminded me of opening the door to a summer cottage that been boarded up for the winter, looking inside, and seeing familiar surroundings."

– Jerry Linenger, NASA Astronaut on his arrival at Mir

Often considered the world's first successful community in space, the space station Mir (Мир) operated in low earth orbit from February 20th, 1986 till final reentry on March 23rd, 2001.

Life in space is very hard on the human body. Studies indicate that living in microgravity for extended periods leads to muscular atrophy and bone demineralization. Maintaining fitness in such a challenging environment is essential during long missions. Astronauts living aboard Mir had access to two treadmills and a stationary bicycle, and their exercise regime mandated daily use of both.

Good nutrition is a critical factor in mission performance, but so is reducing the potential for the introduction of microorganisms. While Mir played host to 28 long-duration human crews, the space station was also home to at least 140 species of microorganisms. These microflora can be quite aggressive too, eating metal and polymer seals. So, to minimize spoilage and reduce the number of tiny travellers, most of the food sent into space is sterilized, thermostabilized, irradiated, or freeze dried.

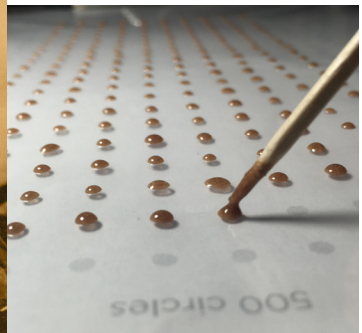
After the fall of the Soviet Union in 1991, Mir also provided a bridge for new international cooperation in space, as the new Russian Federal Space Agency (*Roscosmos*) partnered with NASA for joint missions with the Space Shuttle program. The two agencies developed a protocol for sharing food on their joint missions, and the sharing of such meals helped

STS-81 pilot Brent Jett watches Mir 22 commander Valeri Korzun open a sausage packet with a cleaver.

NASA's STS-74 Atlantis Space Shuttle crew enjoys a meal aboard Mir in 1996.

to provide very human experiences in one of the most challenging of environments.

"The importance of proper nutrition in keeping astronauts healthy cannot be overestimated. The right food is crucial to the success of any exploration enterprise." ~ Joan Vernikos, Ph.D. Director of Life Sciences, NASA



The specimen in the Mini Museum comes from a selection of mission flown food prepared for the space station Mir. The menu includes items from both *Roscosmos* and NASA, including pork goulash, sausage, bread rolls, rice, tinned salmon, and hot cocoa. Each Mini Museum contains a "complete meal", with two dishes (carbohydrate and protein) along with a serving of hot cocoa.

SOURCES:

Lane, Helen W., and Dale A. Schoeller, eds. Nutrition in spaceflight and weightlessness models. Vol. 24. CRC Press, 1999.

Nicogossian, Arnauld E., Sam L. Pool, and John J. Uri. "Historical perspectives." Space physiology and medicine 2 (1994): 3-44.

West, John B. "Historical perspectives: Physiology in microgravity." Journal of Applied Physiology 89.1 (2000): 379-384.

crafting the third edition

"Success is no accident. It is hard work, perseverance, learning, studying, sacrifice and most of all, love of what you are doing or learning to do."

– Pelé

I always say that each specimen has its challenges but in the Third Edition we went further than ever before to try and capture the essence of each specimen.

This led us to experiment with some interesting processes such as plastination (Royal Wedding Cake) and electric discharge machining (Samurai Sword).

While compiling the Companion Guide, I felt like it would be important to share these techniques in more detail. The goal is not just to impart the work that goes into creating each and every Mini Museum but to give a sense of the care and thought that's put into each specimen we create.

Preparing all the specimens for inclusion takes thousands of hours of careful, focused work.

Often, as is the case with Moldavite and Space Gems, a specimen needs to be carefully cleaned before preparation can begin. There are a wide variety of methods for cleaning delicate specimens. In the case of Moldavite, we used an ultrasonic cleaner.

Space Gems required a special acetone bath to remove rust residue from the nickel-iron matrix which surrounded the peridot.

With some specimens, there's the physical aspect of making thousands of cuts. Saws, tile cutters, shears, dozens of nippers of all shapes and sizes.

And as you might suspect, these tools sometimes break or need repair!

Specimens like the Venice and Beatles bricks are the result of many hours spent working with a wet saw. Slices from the original brick are cut into strips and then the strips are cut into tiny “bricks.” These small bricks are examined closely to make sure they have the right shape.

A similar process is used when preparing fossil specimens. Yet, there are always surprises and variations. For example, consider the Megalodon tooth specimen...

Each Megalodon specimen in the Third Edition is comprised of a thin slice of the enamel from a Megalodon tooth. It is difficult to overstate the toughness of this material and in fact the shards pictured here had to be handled very carefully to avoid puncturing our own skins!

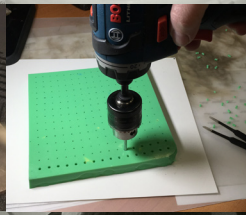
On the other end of the spectrum, the Giant Sloth Claw presented us with an incredibly complex matrix of cancellous or “spongy” bone within the claw.

To preserve this structure we treated the smaller slices with a penetrative stabilizer prior to preparing the final specimens. We wanted to preserve the structure for its beauty of course but also because this spongy structure, which is prevalent throughout the skeleton, is a key to understanding the mechanics of this enormous, presumably slow-moving creature.

Even more delicate specimens like the Egyptian Papyrus required meticulous treatment conducted in several stages to preserve the texture of the material.

While other specimens, like the Transatlantic Cable, involved an intense design process to capture the symbolic essence of the specimen. Here you'll see several steps including the unbundling of the original cable, soaking tests to remove oils and residue, annealing the thinnest wires to make then easier to work with and then assembling an entirely new "wire" by using those pieces in a custom made mold.

This testing process required weeks of trial and error before getting just the right look for the final specimen. Final assembly of thousands of completed specimens took even longer.

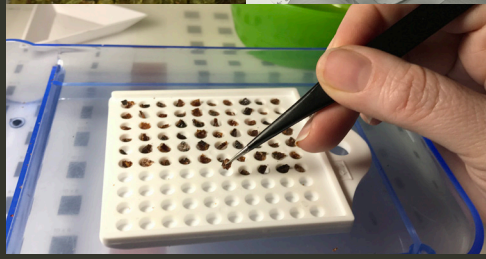


Another specimen which required weeks of preparation is Fordite, though unlike the Transatlantic Cable, Fordite spends most of its time tumbling to produce the final polished specimen you have in your Mini Museum.

But to get to this last step, each piece of Fordite needs to be shaped to reveal the many layers within.

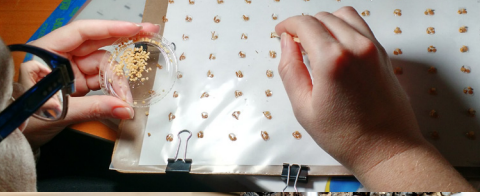
This multi-step process begins with an uncut piece of Fordite. The top layers of paint are removed with a lapidary wheel and the pieces are shaped for visual beauty. From here, there are multiple cutting steps to get to the final angular pieces which will spend weeks tumbling to become the polished beads destined for inclusion in the Mini Museum. Of course, each of those Fordite beads are inspected carefully before making it to the inclusion stage.

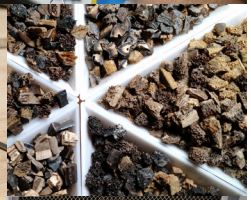
Of course, each stage of preparation is incredibly important but no matter how careful we are it is all for naught if the specimen does not pass the final inspection... and each specimen is carefully inspected (and counted) before moving on.

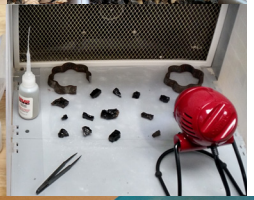


Safety is always an important concern. The tools we use are often very sharp and the substances we work with can be hazardous if proper care is not taken. Of course, the specimens themselves can sometimes have a mind of their own.

Here, a slice of Samurai Sword decided to embed itself in the housing of our lapidary wheel while being polished. Nearly seven hundred years after it was made the steel of this incredible blade was still quite sturdy and sharp.

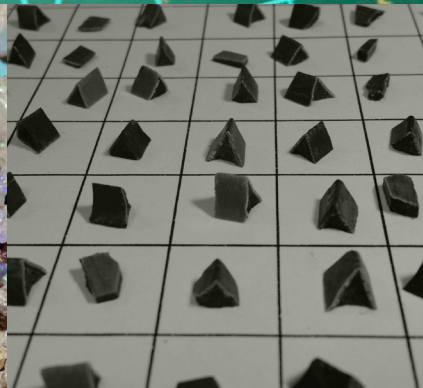






I've shared quite a lot here. In fact, these pictures encompass more than a year of dedicated preparation by the entire team to produce the Mini Museum you are holding in your hand right now. From assembling thousands of tiny "meals," to cutting strips of titanium, the wide variety of life, and the endless counting and grading of specimens.

It's all hard work that we do to make each Mini Museum the best it can possibly be, but it also makes each specimen and each collection absolutely unique.



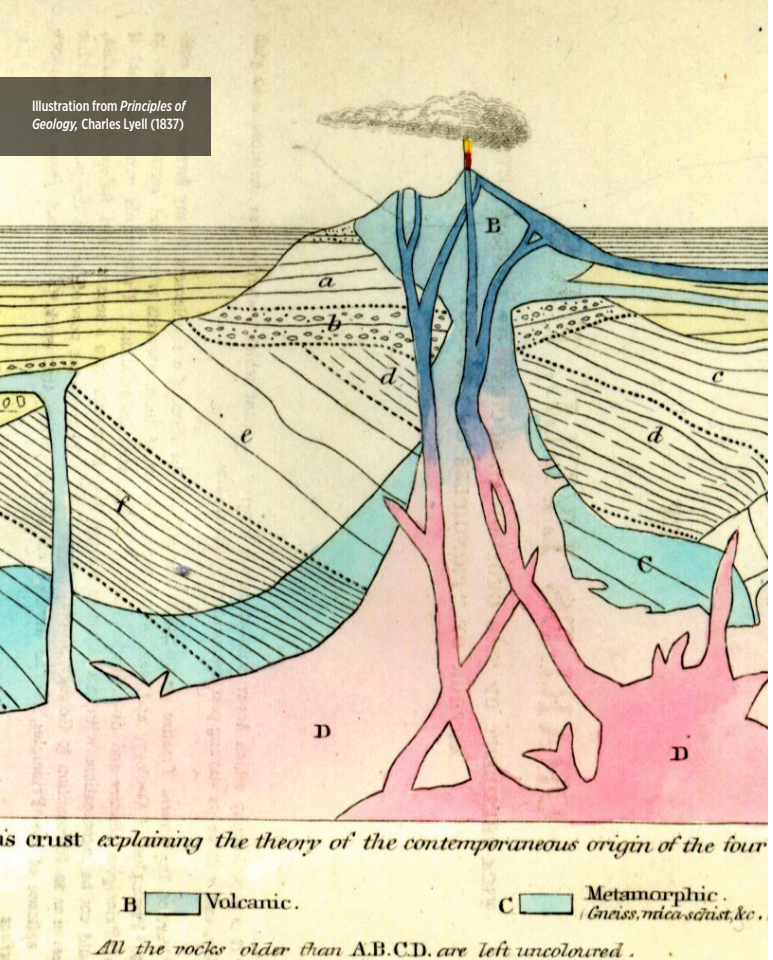


Illustration from *Principles of Geology,* Charles Lyell (1837)

sharing the difficult truths of discovery

"I can only plead that a discovery which seems to contradict the general tenor of previous investigations is naturally received with much hesitation."

– Charles Lyell, The Geological Evidence of the Antiquity of Man (1863)

I've written many times about the adventure of science and discovery, the passion of inquiry, and the joy of sharing that knowledge with others. In this essay, I want to talk about dealing with the difficult truths of discovery and change. I could choose many figures from history to illustrate the challenge, but few were able to drive onward through decades of challenges while maintaining a deep sense of humanity like Charles Lyell.

Charles Lyell (1797-1875) was one of the preeminent geologists of his day. He was particularly interested in volcanoes and geological dynamics as well as in stratigraphy. Using the proportion of specific marine species within certain layers in recent rock strata he was able to propose the separation of the Tertiary period into three distinct epochs (the Pliocene, Miocene, and Eocene). Lyell was also instrumental in helping both Charles Darwin and Alfred Russel Wallace simultaneously publish their work on natural selection in 1858. Later, Lyell published his own geological study about the age of humanity.

Lyell pursued the truth revealed by the data he and others had gathered despite his own personal qualms. He understood these revelations would, over time, force change in thinking far beyond science:

My dear Darwin,

I have just finished your volume,* and right glad I am that I did my best with Hooker to persuade you to publish it without waiting for a time which probably could never have arrived, though you lived to the age of a hundred, when you had prepared all your facts on which you ground so many grand generalisations.

It is a splendid case of close reasoning and long sustained argument throughout so many pages, the condensation immense, too great perhaps for the uninitiated, but an effective and important preliminary statement, which will admit, even before your detailed proofs appear, of some occasional useful exemplifications, such as your pigeons and cirripedes, of which you make such excellent use.

I mean that when, as I fully expect, a new edition is soon called for, you may here and there insert an actual case, to relieve the vast number of abstract propositions. So far as I am concerned, I am so well prepared to take your statements of facts for granted, that I do not think the *piéces justificatives* when published will make much difference, and I have long seen most clearly that if any concession is made, all that you claim in your concluding pages will follow.

It is this which has made me so long hesitate, always feeling that the case of Man and his Races and of other animals, and that of plants, is one and the same, and that if a *vera causa* be admitted for one instant, of a purely unknown and imaginary one, such as the word "creation," all the consequences must follow.

I fear I have not time today, as I am just leaving this place, to indulge in a variety of comments, and to say how much I was delighted with Oceanic Islands - Rudimentary Organs - Embryology - the Genealogical Key to the Natural System - Geographical Distribution; and if I went on I should be copying the heads of all your chapters.

With my hearty congratulations to you on your great work.

Believe me ever very affectionately yours,
- Charles Lyell, October 3rd, 1859

** Origin of the Species*

This is obviously warm and heartfelt praise, written in a moment of joy before rushing out the door. It's something we might dash off ourselves today in an email. But I want to pause for a moment to consider the first sentence: "I am that I did my best with Hooker to persuade you to publish it without waiting for a time which probably could never have arrived, though you lived to the age of a hundred, when you had prepared all your facts on which you ground so many grand generalisations."

Here, Lyell is telling Darwin, who for decades had been hesitant to publish his true thoughts on evolution due to the political and social climate, that the forward path was the right path, even if the work was not perfect... for the work would never be perfect and the world is always changing. Even as I write this, the world is changing and in the midst of this change there are deep challenges we must face.

But how to approach such difficult truths and bring them to light in the world?

Below is a post-mortem tribute to Charles Lyell written by Frances Power Cobbe (right), one of the great social reformers of the 19th century.

The person she describes in very personal terms is one that I would hope that we all might strive to become while moving forward towards the truth.

"The last of the elder generation of our great men of science, Sir Charles Lyell, leaves behind him the memory of a character almost ideally representing what such men should be; so free from egotism, vanity, or jealousy, so ready to be pleased with every innocent jest

or amusement, so ready to listen patiently to the remarks of those infinitely below his intellectual calibre, and withal so affectionate and tender of heart, that no child could be more simple; and, on the other hand, so filled with reverent enthusiasm for the glory and grandeur of the universe to whose study he devoted himself, and so ready to open his mind to each new truth, that no man could better deserve the high title of a true philosopher. Nor did his philosophy, though it released him from some of the bonds of early prejudice, ever lead him to renounce those highest truths to which the lesser ones of science lead up. It was his frequent observation that religious sentiment deserved as much confidence as

any other faculty of our nature, and in full faith and hope in God and immortality he passed calmly into the dark valley of age and death."

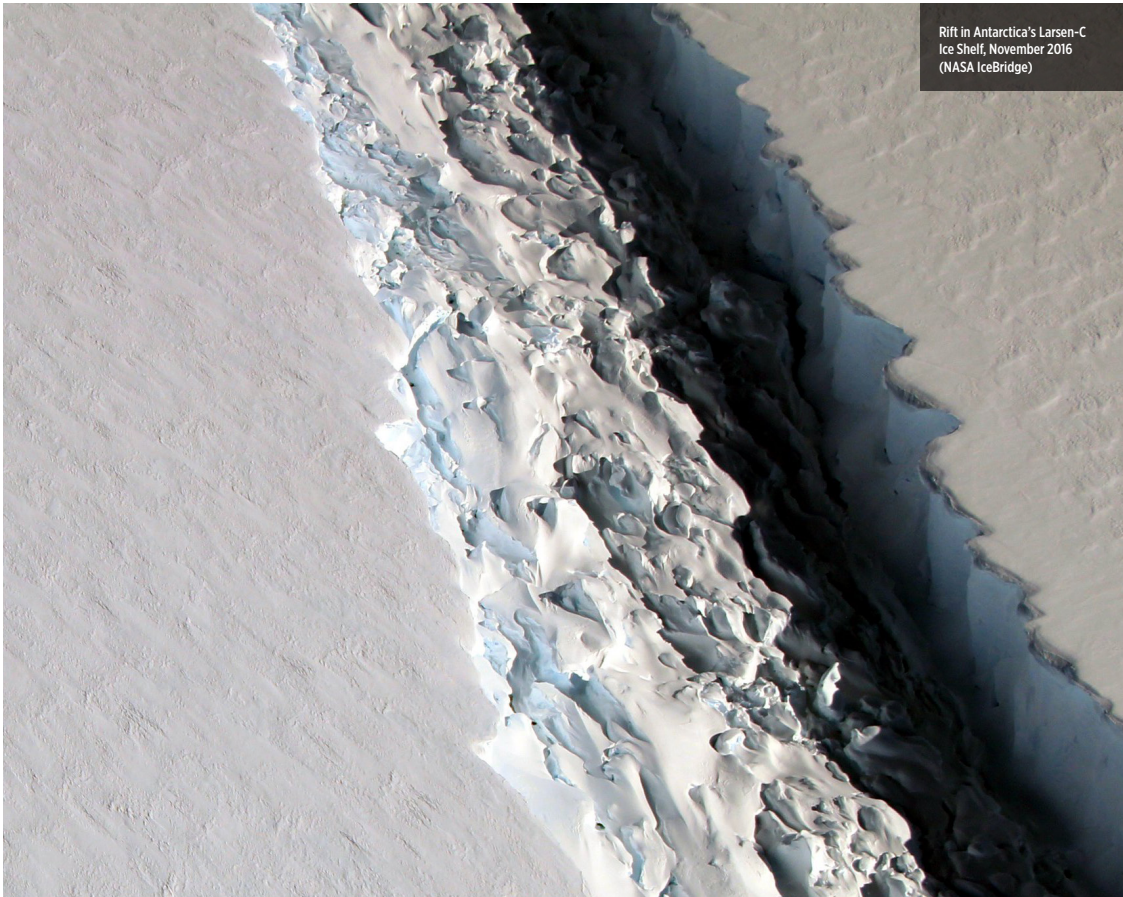
To me, this tribute shows that it is possible to wrestle with difficult truths while maintaining your humanity and compassion for others. It also demonstrates what I believe to be the sort of character required to communicate the difficult truths of discovery: patience and above all kindness.

And we will certainly need all of these attributes in great abundance in the coming decades...

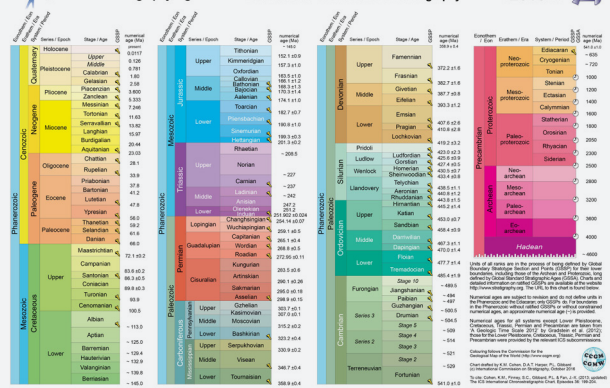
Over the last century, science has recorded change happening on a scale the world has not witnessed for a very long time. There are also new events which have never occurred in the entire history of the planet. And just as Charles Lyell separated the Tertiary Period into three distinct epochs based on clear-headed observations, modern geologists are calling for the recognition of a new geological age called the Anthropocene.

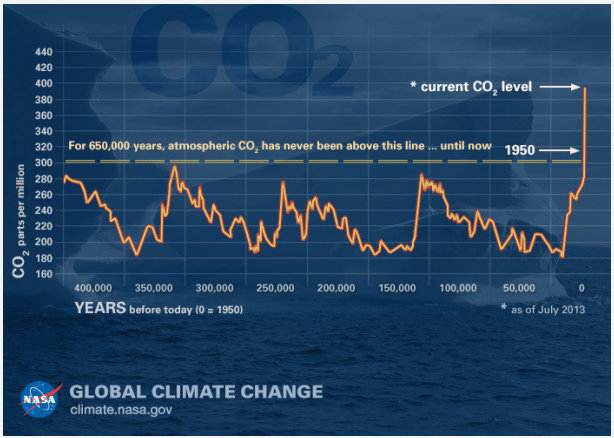
Part of defining a new epoch is settling on a marker or signature in the geological record. The central argument for this new Epoch is that human activity has become so extreme and profound that we have left a permanent imprint on the geological record.

Some scientists have proposed that the Anthropocene begin with Trinity test on July 16th, 1945. Others have suggested a more general marker tied to the introduction of plastics on a mass scale. Numerous studies have also recommend using the rise of atmospheric



Rift in Antarctica's Larsen-C Ice Shelf, November 2016 (NASA IceBridge)





carbon dioxide, tied primarily to the burning of fossil fuels, since we've now surpassed levels unseen any time in the last 400,000 years.

Another marker that will not be apparent in the geological record for some time, but is often used to delineate different epochs, is the extinction of life. According to several studies published in 2014, the current rate of extinction is roughly an order of magnitude higher than at any point in the 60 million years which predated the introduction of humanity into the fossil record.

Change on this scale, in such a short period of time, can overwhelm the mind. It can create divisions and irrational behavior through fear of the unknown. We can lose ourselves in these fears or we can seek to overcome them as Charles Lyell and so many others have done in the past. We must be steadfast in our pursuit of the truth but never lose sight of our humanity.

Above all, we must be kind.

SOURCES:

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We've just covered billions of years of history during the course of this companion guide, but it's not just you and I on this journey. There are over 10,000 Mini Museums in more than 70 countries around the world, including the one you are holding right now.

It may not seem like it all the time, but there are just so many people out there who love science and history. People who care about the world they live in, where we come from, and where we might be going. It is this very connection to a wider world which inspired me to create the Mini Museum in the first place and I find it very inspiring.

Thank you all so very, very much for making this journey possible.


Part A