ZOOLOGICAL MUSEUM

The Eocene

The dawn of our world

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–23.1.22

Contents

The exhibition illuminates a period with climatic conditions different from our own—when Hamburg was submerged under water and subtropical forests covered Germany.

Dr. Ulrich Kotthoff, head of the Geological-Paleontological Museum

Join us on a visit to a world millions of years older than our own and discover the building blocks of life as we know it today.

Marie Rahn, scientific education

We display fantastic objects from our own collections and loans: fossil finds from the Messel Pit and the Geisel Valley as well as inclusions in Baltic and Bitterfeld amber.

Dr. Lioba Thaut,
head of exhibition development

The Eocene in particular shows us how long it takes for evolution to recover from a premature end in the wake of mass species extinction.

Prof. Dr. Matthias Glaubrecht,
scientific director

Two types of fossils, two perspectives: become a paleontologist and study the fauna of long ago using amber inclusions and fossils.

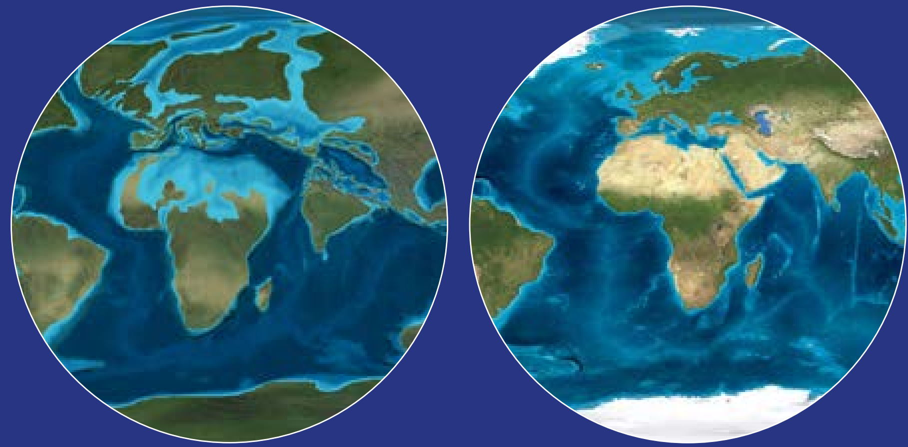
Dr. Viktor Hartung, curator

Eocene—the dawn of our world

Sixty-six million years ago, an asteroid extinguished the majority of life forms. It destroyed a rich spectrum of flora and fauna on land and at sea; for these plants and animals, it was the end of evolution.

It took over 10 million years until species diversity on Earth recovered and our own birds and mammals entered the scene. Roughly 34 to 56 million years ago, in a new phase of Earth's life that we call the Eocene—from the Ancient Greek ἔως or dawn—the flora and fauna of our day came into being.

This occurred under unusually warm climatic conditions, the likes of which we have not seen again since the Eocene. This climate was favorable to the formation of amber, especially the Baltic amber familiar in Germany. Baltic amber yields surprising insights into the past diversity of smaller creatures such as insects and their relatives.



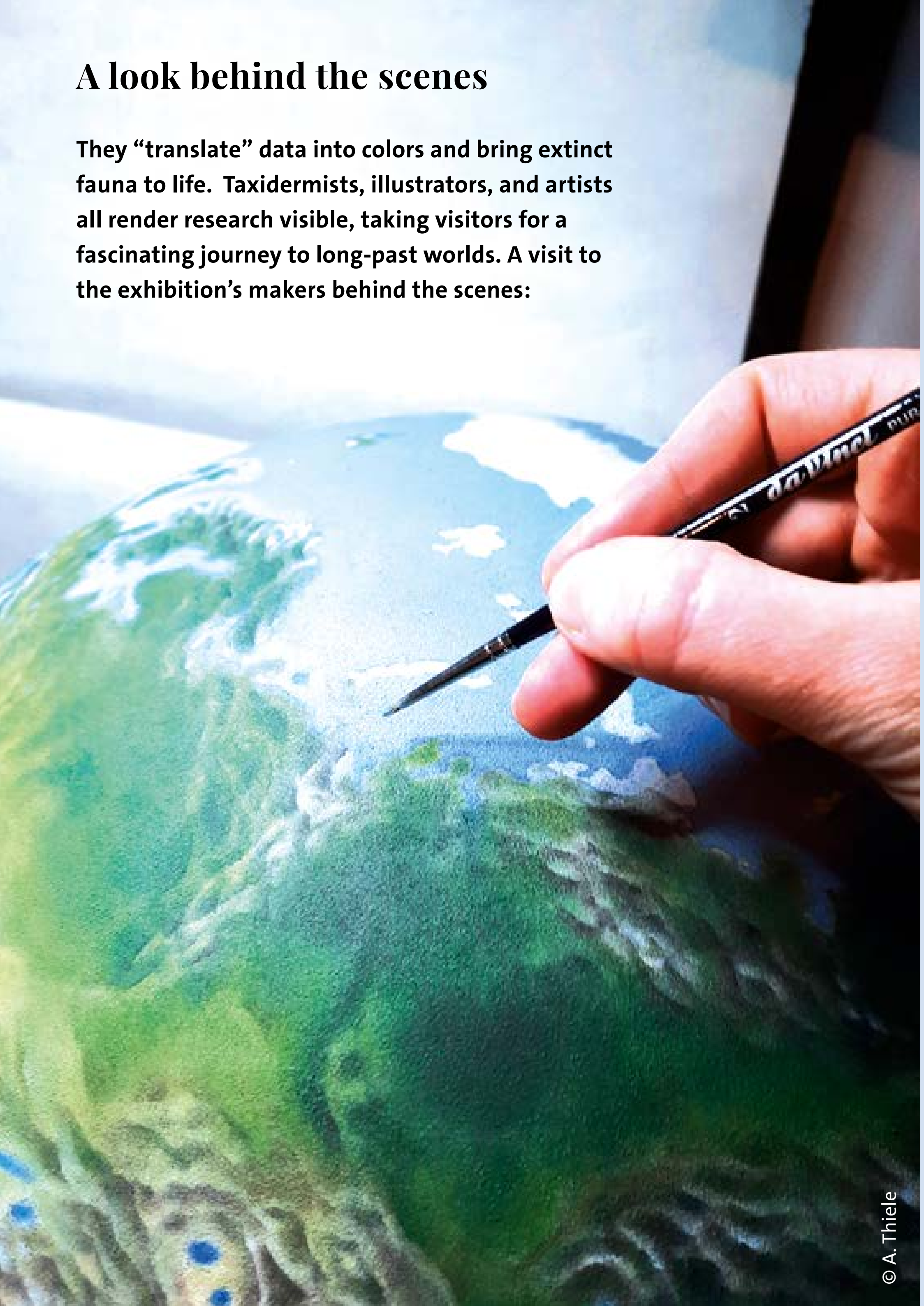
Map of the Earth in the Eocene and now. © R. Blakey

When Europe was like Indonesia

The outlines of the continents in the Eocene closely resembled those of today. Europe and the Middle East, however, had not yet fused to form a single continental mass; they consisted, rather, of numerous large and small islands, similar to the modern Indonesia.
In the Eocene, India and Asia bumped into each other and the collision led to the folding of the Himalayas. At the time, South America and Africa were isolated from other land masses and thus became home to unique flora and fauna.

A look behind the scenes

They “translate” data into colors and bring extinct fauna to life. Taxidermists, illustrators, and artists all render research visible, taking visitors for a fascinating journey to long-past worlds. A visit to the exhibition’s makers behind the scenes:



© A. Thiele

© UHH/CeNak, team taxidermists

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Naturally, not everything is “natural”

On the search for the right specimen, Matthias Preuß is willing to comb through a pine forest. For the tree in the exhibition, the leading taxidermist had very specific criteria: the tree should belong to a species that produces resin and be as similar as possible to those from the Eocene. The size and form of the tree he ultimately selected suits the exhibition perfectly. Nonetheless, Matthias Preuß and his colleagues had their work cut out for them. They had to cut the roots back to the ground-level bulb and add the root endings. The tree needed to seem like an integral part of the entire exhibition. And as a finishing touch, ants (seemingly) scurry naturally along the trunk.

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The perfect optical illusion

For Andrea Thiele, the world is a vast ocean of colors. Using globes, Thiele reveals how the continents and landscapes have changed on our planet, evolving from forested areas in the Eocene to rocky mountains and vast deserts today. “In the Eocene, everything looked green, while on today’s maps, I see a lot of color contrast,” the illustrator explains. She layers the special pastel pigments in great detail on the primed globe. This creates a striking surface. Centralized lighting casts light and shadow for a three-dimensional effect that is nothing short of a perfect optical illusion.

© UHH/CeNak, Team Preparation

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Getting to know an extinct giant bird

Before Matthias Preuß prepares an animal, he intensively studies its anatomy and movements. His goal is to make the animal as true to life as possible. But when preparing the *Gastornis*, a large flightless bird of the Eocene, his hands are tied as he is working on a 3D print of an already-created digital reconstruction. To ensure a coherent overall picture, the taxidermist prepares the surface and colors individual parts to distinguish bones and cavities. Then he mounts the pieces to the best of his knowledge: "We don't know exactly what this extinct bird looked like."

© J. Stoess

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Illusion on a scale of 100:1

Does it bite? Julia Stoess has created such a lifelike pseudoscorpion that it seems real. The perfect illusion. Every one of the artist's arthropod models is based on intensive research. Yet how do you research an extinct animal? Based on photos of similar, present-day pseudoscorpions and using a Zbrush technique, Julia Stoess created a digital model showing the peculiarities of the species that lived in the Eocene. When the template is ready to go, a 3D impression of synthetic resin is created and colored using an airbrush technique. On a scale of 100:1, Julia Stoess completes the process by applying handmade bristles, and then she welcomes the pseudoscorpion to today's world.

Creating an exhibition is like doing an experiment

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Every piece of the Eocene exhibition is unique—every display case, every pedestal, and every panel has been custommade. Martin Reinhardt is a woodworker for exhibitions. He designs and builds the furniture. He chooses the material and experiments when standard techniques don't work. In consultation with the exhibition's designer Julia Pawlowski, he implemented the basic design and adjusted it for the exhibition space. "This all happens in an ongoing process," said Reinhardt. "Only when I begin to build can I refine the details." During the coronavirus pandemic, with all of its limitations, his work has been a race against time.

© UHH/CeNak, P. Pour

Exhibition design: combining fact and fantasy

The Eocene is a long-gone age that ended about 34 million years ago. How do we awaken that era's natural world for an exhibition? And how do we amaze and inspire visitors with our scientific findings, fossils, and fragments? Julia Pawlowski is an exhibition designer who worked together with the Eocene exhibition's scientific curators to give the exhibition its face.

A conversation with Julia Pawlowski

How do you recreate a long-past era on Earth?
To do this, the first thing for me was to consciously break with the usual ways of seeing. The visitors don't just enter a fossilized world of grays and browns; they encounter a very lively world of colors.
The exhibition is divided visually into three parts: blue stands for the meteoric cataclysm, without which the Eocene would not even have happened; green stands for jungle diversity, which characterized the German landscape during the Eocene; and dark red completes the exhibition. Here the focus is on the large amber inclusions, the "sun stones." *Eocene* means *break of a new day* after all.

How does an exhibition help us understand science?
Paleontologists have extensive background knowledge about fossils and other objects from the Eocene that they can immediately call to mind and depict. When museum visitors look at a skeleton fossil, however, they often fail to contextualize it and not realize the importance of the find.
As a communication designer, my job is to make this knowledge and the questions it raises for research as visible as possible. That's why the exhibition is colorful and rich in images. In every nook and cranny, you'll discover an image of a living creature from the Eocene. Photographs and illustrations, for example, symbolize the diversity of organisms and the mosaic-like piecework that is central to scientific pursuit. Thus, the exhibition is to some extent a visualization of current research.

What holds the attention of so many different visitors as they tour the exhibition?
The visitors can get to know the world of the Eocene from many different perspectives. While the jungle room takes us on a journey through time to the early Messel Sea and life in Eocene Germany, the amber room takes a scientist's perspective: How do we study amber inclusions? And what do researchers see when they look through a microscope? For every perspective there are related exhibits, informative texts, and visual focal points. Moreover, in the discovery route, children and their chaperones are playfully led by a "mini-researcher"—a little mascot—through the exhibition.

Julia Pawlowski is a designer who specializes in science communication. She works as an exhibition designer, graphic designer, and consultant on the visual presentation of research work.

What happened beforehand

Death out of the blue

At the end of the Cretaceous period about 66 million years ago, a cataclysmic event on our planet wiped out numerous plant and animal species, including most dinosaurs. The cause was an asteroid about 10 kilometers in diameter. At a speed of over 20 kilometers per second, it hit what is now the Yucatan Peninsula in Mexico. This enormous impact created a huge explosion, the blast- and heat wave of which went around the entire world and triggered massive fires, major earthquakes, and violent tsunamis.

The explosion hurtled so much matter into the atmosphere that it most likely darkened the sun for years, plunging Earth into a kind of frigid, long-lasting winter. The impact also released greenhouse gases that decades later led to significant climate warming.

Thus, our planet's climate changed within a very short time—from warm temperatures to freezing cold to tropical heat. Many animal and plant species on land and at sea did not survive these far-reaching but short-term climate changes.

It took over 10 million years for species diversity on Earth to recover. It was in the epoch we call the Eocene that today's animal world made an appearance, replete with the birds and mammals we are now familiar with. Our current exhibition, *THE EOCENE—Our World's Beginnings* illuminates this period in Earth's history.

The 50,000-year-old Meteor Crater (also known as the Barringer Crater) in Arizona is one of the world's most famous meteorite impact craters. It measures 1,200 meters across and 180 meters deep. It played a major role in research: for the first time, scientists could estimate the age of the Earth (4.36 billion years old) based on meteorites found there. © iStock, D. Jeanmarie

Meteorites—heavenly messengers of destruction

Meteorites are the remains of celestial bodies that have made their way to Earth's surface. There are no known meteorites from the large asteroid that once killed off the dinosaurs because it evaporated upon impact.
This meteorite specimen from the Geological-Paleontological Museum's collection provides only a vague idea of what the "dinosaur killer" could have looked like. It is a fragment of a Canyon Diablo meteorite that left its mark thousands of years ago in the Meteor Crate in Arizona. It measured roughly 45 meters in diameter and weighed 300,000 tons.
There are more awe-inspiring cosmic stones at the Mineralogical Museum in Grindelallee, for example, Germany's largest meteorite: a 424-kilogram iron fragment from Namibia.

Fragment of a Canyon Diablo meteorite 50,000 years old,
Arizona USA, Geological-Paleontological Museum Hamburg

With the extinction of most dinosaur groups, like these horned ceratopsids, many fascinating evolutionary stories have come to an abrupt end. © iStock, D. Eskridge

The doom of the titans

The long-extinct dinosaurs are more familiar to us than some of the animals inhabiting Earth today. About 230 million years ago, during the Triassic, these reptiles made their entrance on the evolutionary stage. They demonstrated an impressive species diversity for about 150 million years, with many spectacular forms. Herbivore or carnivore, they remain the largest land animals in Earth's history.

Not all of them died in the wake of the asteroid's crash 66 million years ago. A small group of feathered species survived. Today, we know these as birds. It took millions of years for our planet to recover from the mass extinction. But after that, in the Eocene, birds and mammals flourished, evolving into the animal world we know today. Our current exhibition, *The Eocene—the dawn of our world* illuminates this exciting period in Earth's history. With the extinction of most of the groups of dinosaurs, many exciting chapters in the evolutionary history finally came to a close.

The trace of the killer

It was not the gigantic crater it left that led scientists to apprehend the "dinosaur killer." The first decisive clue was iridium, a metal rarely found on Earth's surface yet definitely more copious in meteorites. When the asteroid exploded, this iridium was hurtled into the atmosphere and spread all over the world.

A rock layer with an unusually high concentration of iridium has been discovered in many places since the 1970s. The layer is generally invisible to the naked eye, which is why chemical methods are used to prove its existence.

The age of the rock layer corresponds to the mass extinction 66 million years ago. This is why scientists suspected that an asteroid might have caused species extinction. The Chicxulub crater in Mexico was discovered only later, in 1991, following a long search.

The german jungle

Life's new diversity

Mammals and dinosaurs emerged at roughly the same time. However, while dinosaurs soon developed into huge creatures that ruled Earth for 135 million years, mammals long remained discreet insect-eaters and small-animal hunters; above all, they were nocturnal.

About 10 million years after the dinosaurs disappeared, the mammals began to multiply and take on many new forms, among them horses, bats, primates, and pangolins. Many of the "European" groups of the age, such as the opossum, now live only outside of Europe.

Not all of these species survived the Eocene: the rare *Leptictidium*, which hopped like a kangaroo, for example, or the earlier predators *Lesmesodon* and *Buxolestes*, that are not related to today's carnivorans.

The Eocene's birds also seem both familiar and strange. There were tropical species such as parrots and huge cursorial, or flightless, birds such as the *Gastornis*. Gar ambushed frogs and turtles in the water. Crocodiles counted among the most dangerous hunters on land and in water and could grow up to four meters long.

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1 Crocodile *Diplocynodon darwini* (Ludvig, 1877) Messel Pit, 47 million years old, replica. One of the most common Messel crocodile fossils, Geological-Paleontological Museum Hamburg © UHH, RZZ/MCC, A. Mentz
2 Water lily leaf, Nymphaceae family, Messel Pit, 47 million years old, original. One of the most common plants in the Messel lake, Geological-Paleontological Museum Hamburg © UHH, RZZ/MCC, A. Mentz
3 Prehistoric horse *Propalaeotherium parvulum* Laurillard, 1849, Messel Pit, 47 million years old, original. One of the first horses in history, Geological-Paleontological Museum Hamburg © UHH, RZZ/MCC, A. Mentz

Fossils and colours

The colors used for extinct animals in films and in images almost always have their origins in more or less well-founded fantasy. When fossils develop, their colors are strongly affected by the surrounding rock. Generally, they do not retain their original pigments.
Some finds from the Messel Pit, however, are the exception: The jewel beetle on display here shimmers just like it did 47 million years ago. Its colors have remained visible because they are created by the beetle's special surface texture, not by pigment.
However, in the Messel Pit, not all hues are authentic. The conspicuous white spots on the *Macropunctum* click beetle, for example, appeared only in the process of fossilization.

Jewel beetle, Buprestidae family, Messel Pit, 47 million years old, slab of oil shale with the original. Beetle from a family that today is mostly found in the tropics, Loan from the Hessisches Landesmuseum Darmstadt © UHH/CeNak, T. Daalsgard

Messel—evolution's treasure trove

The Messel Pit is located just 15 kilometers northeast of the German city of Darmstadt. Forty-seven million years ago, during the Eocene, it was a crater lake in an active volcano area. Rising toxic underground gases regularly killed animals in the water and the surroundings. When the cadavers sank to the bottom of the ancient Messel lake, they remained almost entirely intact thanks to the lack of oxygen. Thus, there was virtually no organic decay.

In the course of millions of years, the lake's mud turned into oil shale and the embedded animals fossilized. Their extraordinary preservation allows us to precisely document a very significant period in animal evolution.

For these reasons, the Messel Pit Fossil Site became the first German UNESCO World Heritage Site in 1995. Incidentally, just a few years earlier, there had still been plans to create a landfill right there!

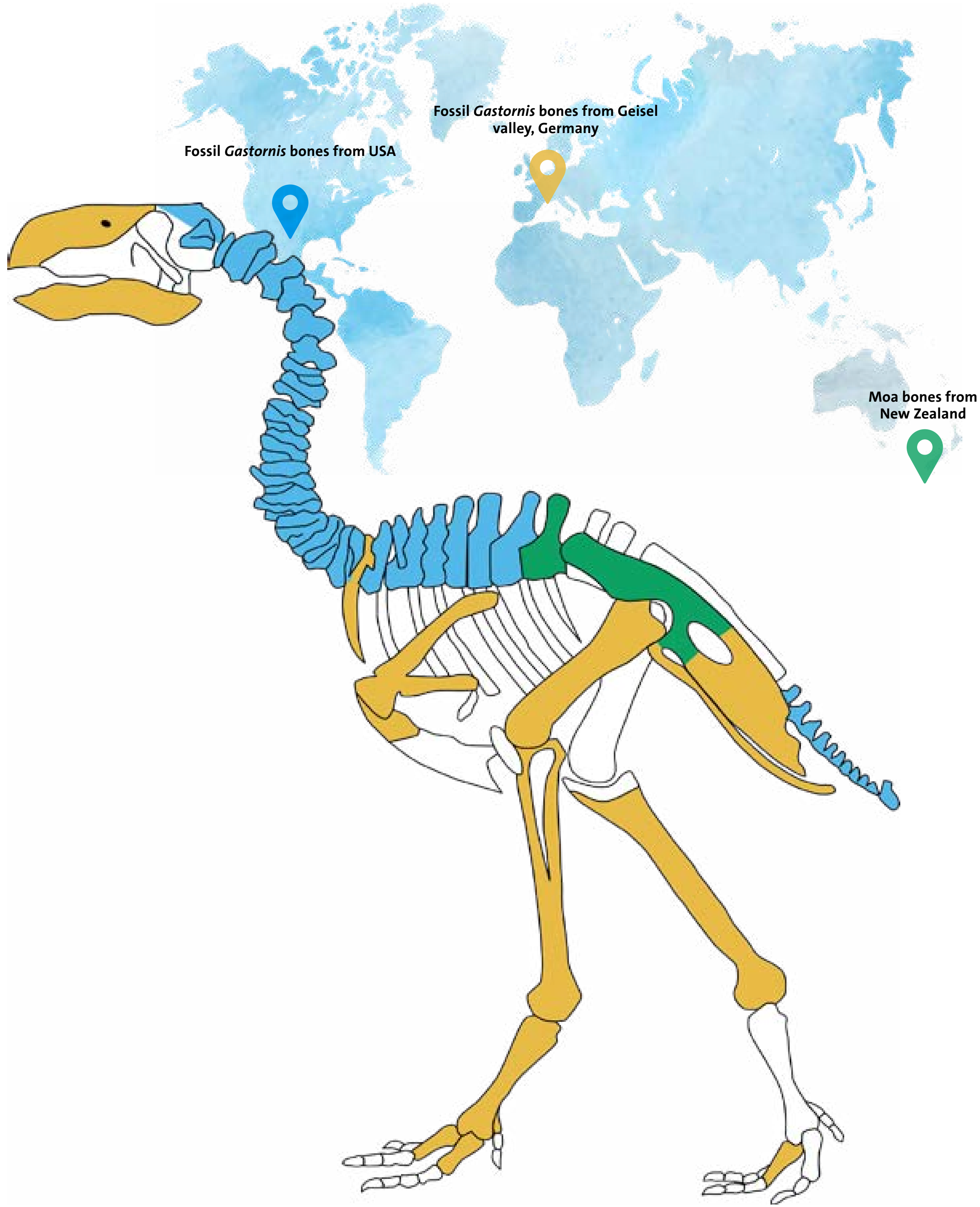
1 The Eocene Messel lake might have looked similar to this modern crater lake. © Unsplash, M. Elías
2 The Messel Pit in June 2011. © UHH/CeNak, M. Rahn

Making a complete bird from a few bones

During the Eocene, the huge flightless bird *Gastornis* inhabited Europe, North America, and Asia. However, as so often with fossils, no complete skeleton has yet been found.

Thus, researchers have reconstructed the bird from bones recovered in the Geisel Valley in Germany and in the United States. Nonetheless, the resulting puzzle remained incomplete. Important additional cues on the pelvic structure came from the bones of New Zealand moas, although these giant birds lived millions of years later.

This is a typical method in the field of paleontology, the study of organisms from long ago. Paleontologists often work with incomplete data that need to be supplemented with information from other sources. The skeleton on display reflects our current understanding. Future research will determine whether we need to change our image of the *Gastornis*.



The finds from different regions contributed to the reconstruction of the *Gastornis* skeleton. © After Hastings & Hellmund, 2015

Hunter or herbivore?

For a long time, the *Gastornis*, which could grow up to two meters and weigh 175 kg, was considered the unrivaled ruler of the Eocene jungle, the most dangerous hunter of its time, terrifying small ancient horses and other mammals.
Perhaps, however, the *Gastornis* was not so dangerous. Its jaw muscles were much closer to those of today's plant-eating birds than to those of meat-eating birds. Furthermore, the chemical signal of the calcium isotope in *Gastornis* fossils corresponds to that of a vegetarian. So it was most likely not a predator, even if we do not yet know more about its diet.

Muscles of a herbivore?
The attachment sites of the lower jaw muscles are very pronounced in *Gastornis*, just as in herbivore birds.

Tears of gods, resin of trees

The Ancient Greeks were already familiar with Baltic amber. Greek myth has it that Phaeton, the son of the sun god Helios, once wished to steer his father's chariot. Helios used this to drive the sun around the world. Phaeton's ride ended in a catastrophe that also proved fatal to him. His sisters cried for him and, as the myth would have it, their tears turned to amber.

The reality is both more prosaic and more miraculous. Amber emerges when trees produce resin that "fossilizes" millions of years later. The warm climate of the Eocene was particularly favorable to resin formation.

Sometimes, organisms get trapped in the resin. These are usually small animals such as insects. A single drop of resin can completely envelope them. Larger mammals or birds are rarely found in amber; only single body parts remain sometimes in the sticky substance. The pieces conserved in amber were very well preserved and reveal a great deal about the organisms of long ago.

An ant stuck in tree resin.
© UHH, RZZ/MCC, A. Mentz

Same species, different fossils

Although Baltic amber and fossils from the Messel oil shale emerged at the same time and in similar habitats, they reflect very different animal worlds.

For example, in Messel, scientists have found the larvae of the caddis fly, which lives exclusively in water. In the amber, however, only adult caddis flies, which could fly to the resin-producing trees, have been preserved. In Messel, it is above all aquatic animals that have been preserved, as well as animals that fell into the water. Amber, however, preserved those organisms taken by surprise as they sat on a branch or the ground.

Even when scientists discover the same species in the oil shales of Messel and Baltic amber, they find differences. For example, beetles retain their colors in oil shales if the colors are produced by the special texture of their surface. The yellowish quality of amber distorts colors, but the organisms retain their delicate body parts, such as legs and antennae—which rarely survive intact in oil shale.

Thus, different fossils provide different clues that, when we put them together, create a more detailed picture of insects of the past.

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1 Termite, inclusion in Baltic amber, 54–40 million years old, Geological-Paleontological Museum Hamburg © UHH/CeNak
2 Termite, Messel Pit, 47 million years old, slab of oil shale with the original fossil. Member of a group found today exclusively in warmer regions. Loan from the Leihgabe Hessisches Landesmuseum Darmstadt © UHH/CeNak, T. Daalsgard
3 A case of a caddis fly larva, built from grains of sand, Messel Pit, 47 million years old, slab of oil shale with the original fossil. Loan from the Hessisches Landesmuseum Darmstadt © UHH/CeNak, T. Daalsgard

Biodiversity research: the end as a new evolutionary beginning

After the dinosaurs died out at the end of Earth's middle age, new species of birds and mammals "conquered" the planet. Matthias Glaubrecht, CeNak's scientific director and professor of the biodiversity of animals at Universität Hamburg, looks at the almost equally abrupt end of biodiversity's heyday in his book *Das Ende der Evolution. Der Mensch und die Vernichtung der Arten (The end of evolution: humankind and the destruction of species)*. This time, human beings are the cause of species loss—as they continue to destroy natural habitats.

A conversation with Matthias Glaubrecht

Are we in the midst of mass extinction and can we still avert "the end of evolution"?
Indeed, species loss began in the second half of the twentieth century, mostly without anyone taking notice. It has increasingly accelerated for the past two, three, or four decades as the world population has grown. In the coming decades, experts expect, on the one hand, 2 to 3 billion more people who will all have to be fed and thus exert greater pressure on natural habitats. On the other hand, studies conducted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) predict that up to 1 million species will become extinct. We can halt this only if we leave more room and give it back to other species.

Dinosaurs became extinct before the Eocene. What has remained of them, evolutionarily speaking?
The group of dinosaurs was phenomenally successful for over 150 million years. They did not die out because their time had passed or they had failed to adapt—as people always erroneously believe. Most dinosaur lines ultimately died out because a meteorite destroyed Earth's habitats 66 million years ago. Of the species at the time, only the ancestors of today's birds survived. These include, for example, the *Gastornis* of the Eocene, a flightless relative of the goose, as we show in the exhibition. For a long time, the bird was considered predatory, like earlier dinosaurs, but it could very well have been a stolid herbivore.

What makes the Eocene special and what fascinates you as an evolutionary biologist?
After the catastrophe, which not only put an end to dinosaurs but also to the majority of flora and fauna, it took many millions of years for biodiversity to recover. It was only with the emerging and aptly named Eocene—the "dawn" of a new age roughly 56 million years ago—that new and diverse organisms among mammals and birds, for example, emerged. This coming and going of the animal world in the course of evolution fascinates me and it should also teach us about how to treat biodiversity today.

Prof. Dr. Matthias Glaubrecht heads the Center of Natural History (CeNak) as its scientific director. The evolutionary biologist is professor of the biodiversity of animals at Universität Hamburg.

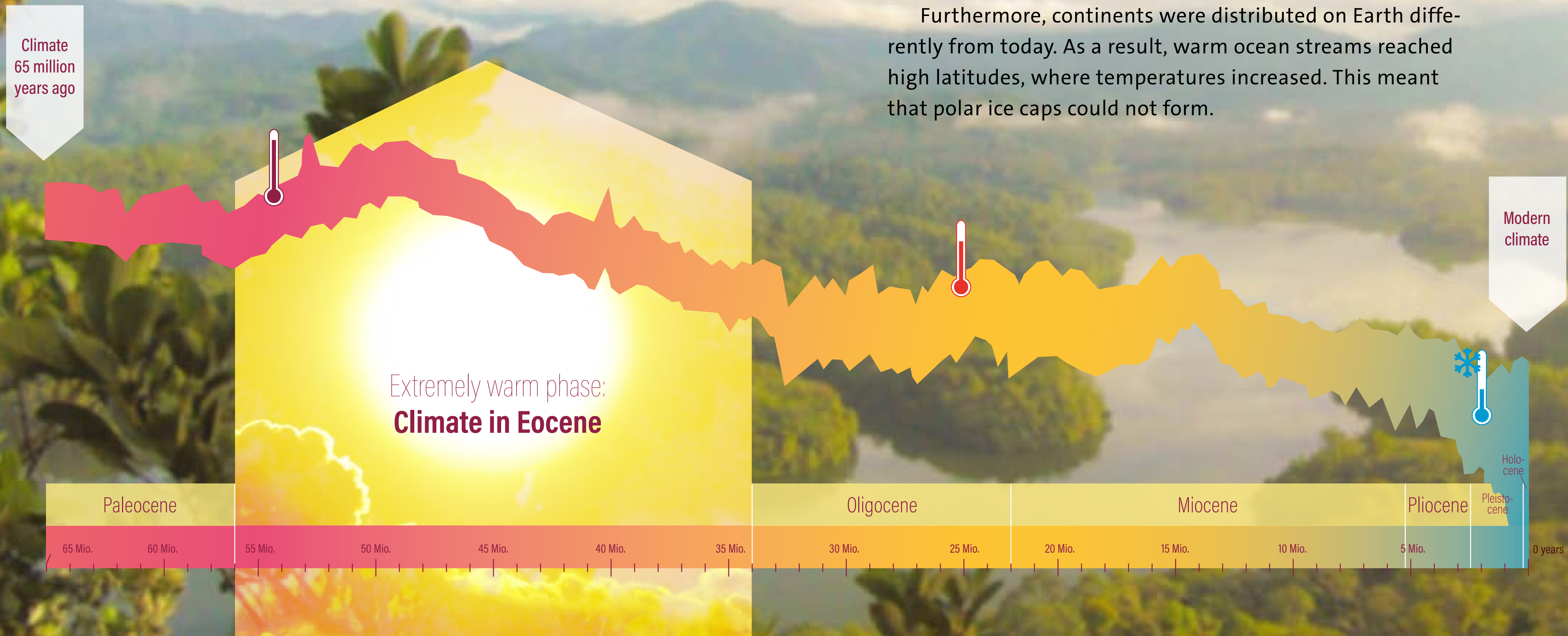
Biodiversity and climate

Greenhouse Earth

During the Eocene, it was extraordinarily warm because the greenhouse effect strongly impacted the climate. Climate findings for the Eocene even allow researchers to better understand the current climate change.

The concentration of carbon dioxide (CO_2), still one of the most important greenhouse gases, was unusually high in the Eocene. While certain rocks and minerals bind CO_2 as they weather, they were too rare on the Earth's surface at the time to prevent warming.

Furthermore, continents were distributed on Earth differently from today. As a result, warm ocean streams reached high latitudes, where temperatures increased. This meant that polar ice caps could not form.



The chart shows the marine temperature fluctuations since the extinction of the dinosaurs. The data result from the proportion of certain carbon forms in microorganisms that changes with the temperature.
© after Zachos et al. 2008

Climate researchers' drill

The climate of the past can best be investigated deep below the Earth's crust, for example, on the ocean floor via ocean drilling.

Projects of this kind involve specialists from many different disciplines, for example, experts on extinct organisms, microorganisms, deposits, and rocks. From a research vessel, they drill deep into the ocean floor using cutting-edge technology. Sediment samples in the form of narrow columns are then hauled up piece by piece. The more recent deposits are closer to the top—the older ones on the bottom. In this way, they keep yielding information about a specific period in Earth's history.

CeNak is also involved in these kinds of international drilling projects. You can find out more at the Geological-Paleontological Museum, Bundesstraße 55.

View from below of the drilling rig of the Greatship Manisha, during a scientific drilling project in the Baltic Sea. © C. Cotterill

Broad-leaf forests in the Arctic

The shape of tree leaves strongly depends on the climate, even if researchers have not yet found a definitive explanation for this. While leaves in moderate climates, such as in modern Germany, are usually tooth-edged, tropical leaves are more often smooth-edged. If fossilized leaves with smooth edges predominate in a specific period, as they did in Germany during the Eocene, this suggests that the climate was warm.

During the Eocene, broad-leaf trees could also be found in Greenland or on the Spitsbergen in Norway. Their leaves were tooth-edged; it was therefore not very warm in those places but still much warmer than today. Now, normal-size trees can no longer survive in these cold regions.

Fossilized leaves, Eocene, approx. 50 million years old, Svalbard
Geological-Paleontological Museum Hamburg

The Deadly Five

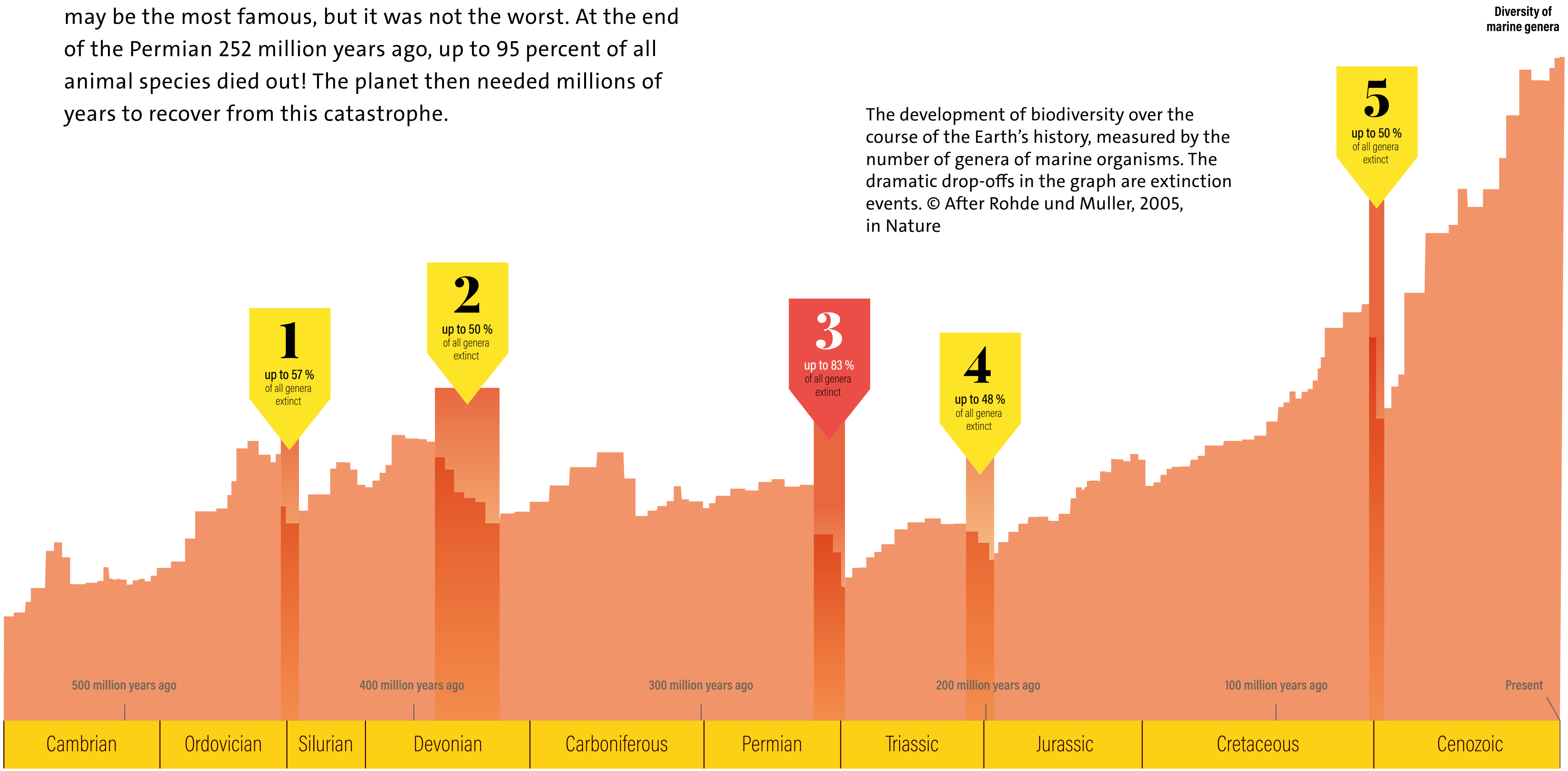
The diversity of life, or biological diversity, has dwindled several times through Earth's history due to various crises. To date, there have been five mass extinctions that led to the disappearance of many species in a very short time.

The mass extinction at the end of the Cretaceous Period, which is the one in which the dinosaurs also became extinct, may be the most famous, but it was not the worst. At the end of the Permian 252 million years ago, up to 95 percent of all animal species died out! The planet then needed millions of years to recover from this catastrophe.

Researchers have been investigating the causes and respective developments in these mass extinctions intensively. The climate and volcanism seem to be the most frequent factors, though much remains to be explained.

What we do know with certainty, however, is that the speed of species extinction in our era is so fast that we can justifiably speak of a sixth mass extinction. And it is being caused by humans.

The development of biodiversity over the course of the Earth's history, measured by the number of genera of marine organisms. The dramatic drop-offs in the graph are extinction events. © After Rohde und Muller, 2005, in Nature



Protists‘ tale of prehistory

Examining fossilized microorganisms such as foraminifera is an effective way to study the past climate. These single-celled organisms, or protists, develop shells with many chambers and still inhabit Earth today, primarily in the ocean. The chemical composition of the shell provides information about the climatic and environmental conditions that dominated during the organisms’ lifetimes. Since the various foraminifera species needed very different kinds of habitats, researchers can reconstruct the climatic conditions based on the species composition of these protists in a sample.

Model of a foraminfera, *Hantkenina compressa* Parr, 1947,
a single-celled organism that was widespread during the Eocene.
Scale 1600:1, Geological-Paleontological Museum
© UHH, RZZ/MCC, A. Mentz

Paleo climate research: back to the future

Ulrich Kotthoff looks at the past to understand the future. Pollen seeds and single-celled organisms in ocean and lake deposits, fossilized insects, and organisms conserved in amber provide the head of the Geological-Paleontological Museum at CeNak with detailed information about life in past eras of Earth's history, for example, the Eocene. This allows him to reconstruct earlier ecosystems and investigate changes in the past climate.

A conversation with Ulrich Kotthoff

Paratype of the stingless bee *Succinapis micheneri*,
Baltic amber inclusion, Geological-Paleontological Museum.
© UHH/CeNak

The Eocene ended more than 33 million years ago. How precisely can paleontologists study life from so long ago?
From a geoscientist's point of view, the Eocene is not actually that long ago, so we have a relatively high number of "windows" onto the period. These include deep-sea deposits and rock deposits from earlier lakes that we can examine by drilling. The Messel Pit near Darmstadt is a good example for this kind of lake. There, we can also excavate large areas.

How do drilling projects and excavations help you recreate past ecosystems?
To stick with the Messel Pit— we researchers can find pollen seeds, the remains of plants, and microorganisms in rock deposits. This allows us to reconstruct the vegetation surrounding the earlier lake as well as the microflora and microfauna in the water of the period. Since older deposits generally lie at the bottom, we can gain an overview of what the flora and fauna looked like at different times. Moreover, excavations allow paleontologists to find larger plant and animal fossils, giving us a comprehensive picture of an entire ecosystem, from the lurking crocodile and the small, ancient horse to the grapevine and freshwater algae.

Alongside the Messel fossils, what does amber add to our understanding?

In Europe—for example, in Bitterfeld—we have a few large amber deposits that are probably only a bit more recent than the fossils from Messel. Danilo Harms, from the Department of Arachnology, and I are currently working in a project on the arachnids preserved in these deposits. Amber provides clues to larger organisms only seldom, but we can find very well-preserved smaller animals, plant remains, and fungi. Furthermore, we can find animals encased in amber that we normally do not find in sea deposits. The amber is thus another important window onto past ecosystems.

Why are you currently studying arachnids?

A few arachnid groups preserved in amber have not yet been studied in detail. Thanks to cooperation with DESY, we now have high-resolution scans that yield new insights. These 3D images allowed us to show the existence of an arachnid family, for example, that we previously knew only in its modern manifestation. Now we know that it already existed in the Eocene.

To some extent, arachnids have very specific ecosystem and climate needs. Thus, they can help us check and optimize our climate reconstructions, for example, for the Eocene, and better understand the evolution of habitats.

And what can the Eocene now teach us about the current climate warming?

Paleo climate researchers are reaching congruent conclusions using very different reconstruction methods. In the Eocene, especially in the early Eocene, we had significantly warmer conditions coupled with higher concentrations of atmospheric CO_2 and other greenhouse gases. The sea level was about 50 to 100 meters higher than it is today. Northern Germany was at least partially covered by the predecessor of today's North Sea. Here, we experienced more subtropical to tropical conditions. In the Messel region, for example, there were crocodiles and thermophilic turtles.

The Eocene therefore provides us with a possible scenario for the world's development if we are not careful with greenhouse gas emissions. We still have to remember, however, that the continents in the Eocene were arranged somewhat differently. In addition, some of today's changes caused by humans run their course very quickly.

Ulrich Kotthoff is a paleontologist and heads the Geological-Paleontological Museum at CeNak.

The many facets of the “sun stones”

The world of amber

Baltic amber is the most famous type of amber in Germany. But there are also other deposits—in Bitterfeld, for example. Numerous others are spread all over the world in many countries. All amber has one thing in common—namely, it is fossilized resin. The resin may come from very different types of trees, however, and the most varied geological processes can affect it. This is why there are numerous varieties and a broad spectrum of hues.

Amber deposits also hail from very different periods. There is resin in carbon deposits from 320 million years ago that has survived to today. And even today trees produce resin that could form amber in millions of years.

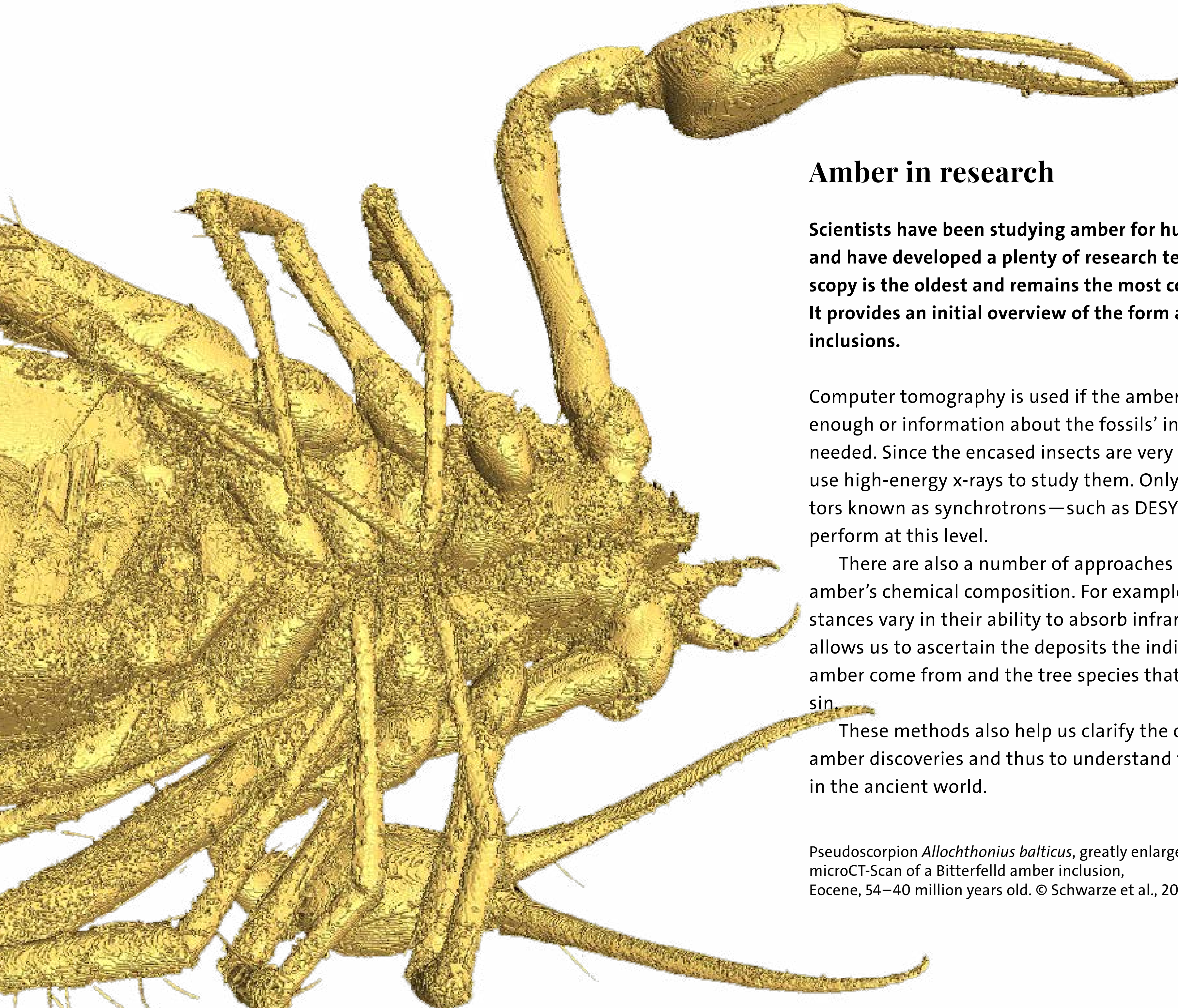
In addition to fresh resin and “mature” amber, there is an interim stage in amber development called *copal* that is “merely” a few thousand years old. You can often find this in tropical regions, for example, in Madagascar or Columbia.

Space and time travel

Baltic amber is 40 to 54 million years old. Many animal groups whose representatives we find entrapped in amber have either died out or are no longer indigenous to Europe, for instance, because they were only able to survive in warmer regions. One example are the pseudoscorpions of the Pseudotyrannochthoniidae family..

Studying fossils in Baltic amber is like traveling through space and time. For example, we can determine whether Eocene deposits in Europe—such as Baltic, Bitterfeld, or Ukrainian Rovno amber—came from the same forest. Or whether they came from different trees in different areas at very different times. At CeNak, we get to the heart of these questions, for example, by studying the arachnids in these amber deposits. If the species trapped in them differ, then we can make a good argument that the amber comes from different regions.

Winged termite *Reticulitermes minimus* Snyder, 1928, Baltic amber inclusion, Eocene, 54–40 million years old. Today, termites are limited to tropical and subtropical regions. © UHH/CeNak



Amber in research

Scientists have been studying amber for hundreds of years and have developed a plenty of research techniques. Microscopy is the oldest and remains the most common method. It provides an initial overview of the form and structure of inclusions.

Computer tomography is used if the amber is not transparent enough or information about the fossils' inner structures is needed. Since the encased insects are very small, we need to use high-energy x-rays to study them. Only particle accelerators known as synchrotrons—such as DESY in Hamburg—can perform at this level.

There are also a number of approaches used to analyze amber's chemical composition. For example, different substances vary in their ability to absorb infrared radiation. This allows us to ascertain the deposits the individual pieces of amber come from and the tree species that produced the resin.

These methods also help us clarify the origin of ancient amber discoveries and thus to understand the trading routes in the ancient world.

Pseudoscorpion *Allochthonius balticus*, greatly enlarged,
microCT-Scan of a Bitterfelld amber inclusion,
Eocene, 54–40 million years old. © Schwarze et al., 2021

The gold of the North

Many people believe that you can find amber primarily on the beach. You may, indeed, get lucky at the North and Baltic Seas, but only because the waves wash ashore pieces of amber from sediment layers.

These pieces actually come from "blue earth"—a specific sediment layer. You can also find this in many places on the Baltic. This layer does not even lie especially deep in the ground, which means that amber can be excavated using diggers. Finds on the beach may be more modest: amber is also often confused with other types of matter such as glass, plastic, or in the worst case phosphorous from the remains of munitions.

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1 Polishing of an amber piece. © iStock, imantsu
2 Amber bracelet from East Prussia, loan by the Preuß family. © UHH, RZZ/MCC, A. Mentz

Amber is soft, malleable, and easy to polish. It lends itself well to all kinds of carving and turnery. Even human beings as far back as the Stone Age made artistic objects using this "sun stone." Today, we still use amber for jewelry and decoration.

Furthermore, amber has unique insulating properties that can be used in electronics. Everyday words such as electronics and electricity and even the term for the elementary particle electron come from the ancient Greek word for amber: ἤλεκτρον.

Blood amber?

Amber has fascinated people since the Stone Age and has always been precious. Where money is involved, however, there is a potential for conflict and exploitation—of both people and the environment.

The same extraction methods can have completely different consequences for the environment, depending on the social and economic context. For example, the hydraulic method of mining amber is unproblematic if the procedure is regulated through licensing and environmental restrictions are heeded. But when there are no regulations in place, when there is no environmental awareness, and when too many people, driven by poverty, mine amber using this technique, grave environmental problems—such as those seen in Rivne region in Ukraine—are the result.

Amber is even used to finance armed conflicts, for example, in Myanmar (Burma). There, the central government is fighting a rebellious provincial army, one of the conflict points being the control of amber mines.

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1 Burmese amber comes from the Kachin State in Myanmar. In the last several years, this has been the site of repeated armed conflicts between the central government and separatists. © H. Lat
2 There is widespread illegal mining of Ukrainian Rovno amber. These illegal mine pits have turned entire swaths of land into a moonscape. Source: https://vk.com/public113496902

Lifelong learning: creating eureka moments for everyone

Reaching a diverse public by diverse means is important to all of CeNak, but especially to Marie Rahn, acting head of the scientific education department. Her work on permanent and special exhibitions, her team's extensive experience, and her diverse didactic approaches ensure that a visit to the museum is always fascinating and memorable, regardless of age or background.

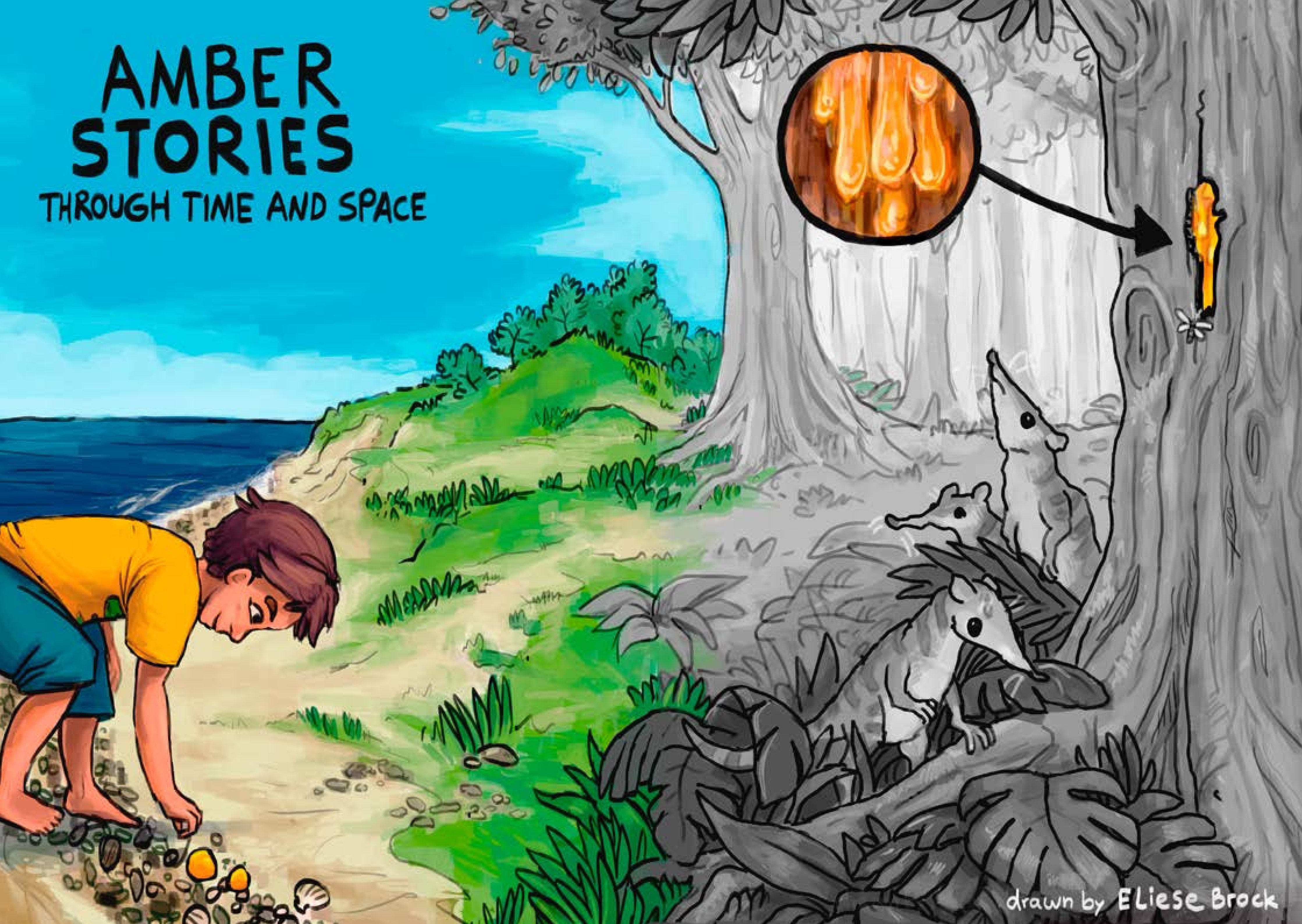
A conversation with Marie Rahn

There's a Discovery Route in the Eocene exhibition. Tell us what that is, and who it's meant for.
In all parts of the exhibition, our Discovery Trail offers visitors various approaches to a world that is so far in the past, that we, today, can hardly begin to imagine it. The separate stations are primarily designed for families with children, but have something for people of all ages. Each one stimulates different senses, encourages you to look more closely and reflect on it, and poses questions that can be discussed by the entire family. Together we explore the question of what answers science can give us and where its limitations lie.

What else does the Eocene exhibition have to offer in the way of lifelong learning?
The original objects, illustrations, and the tie-ins to current research provide an ideal basis for all kinds of communication formats, depending on the motivation, previous knowledge, and interests of our visitors. With tours, workshops, and analog and digital extras, we can shine a light on the details of all of the partial aspects and each of the living organisms in the exhibit, show further connections, and bring in new perspectives from our visitors. That's how we keep it lively!

The special exhibit is only on for a limited time. Will it have a longer and regionally wider-spread effect?
Each time we plan a new exhibit, we learn for and from our visitors, and expand what we can offer them. The pandemic experience has intensified our desire to put more details online—with no space or time constraints—like the comic we had drawn especially for us, which offers a peek at the exhibition. This exhibition could not have come together without the help of various sponsors, partners, and lenders. We look forward to the continued productive exchange in the wide and well-established networks that made it possible.

Marie Rahn is acting head of the scientific education department and visitor management. With more than 20 years experience as a museum education and exhibit curator, she makes CeNak's knowledge, research, and collections available to the public.


AMBER
STORIES
THROUGH TIME AND SPACE
drawn by Eliese Brock

Legal notice of the special exhibition

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Exhibition plan of the Zoological Museum