

Environmental Sins from Prehistoric Times

Human beings are currently changing the Earth on an unprecedented scale. But when did the transformation of our planet begin – and with it the human age, the Anthropocene? For archaeologists, the answer is clear: humans have been shaping the world's ecosystems for tens of thousands of years. **Nicole Boivin** and her team at the **Max Planck Institute for the Science of Human History** in Jena are using new methods to search for the earliest traces of human activity – and getting involved in current debates surrounding the Anthropocene.

TEXT UTE KEHSE

The scars on the landscape, the quarries in the middle of the Arabian Peninsula, can even be spotted on satellite images. The dark volcanic rocks must have been cut away on an almost industrial scale at one point – and that at a time when *Homo sapiens* had yet to appear on Earth. As far back as hundreds of thousands of years ago, prehistoric humans of the species *Homo erectus* produced simple tools, hand axes, from the hard volcanic rock. “These people altered the geological outcrops across a vast strip of land measuring over 150 kilometers in length,” reports Michael Petraglia, Professor of Human Evolution and Prehistory at the Max Planck Institute for the Science of Human History in Jena. “They took

Human traces everywhere: As finds in the Batadombalena Cave show, Sri Lanka's tropical rainforest was populated by humans as far back as 36,000 years ago. These early inhabitants used ingenious methods for hunting and trapping in order to survive in the hostile environment.





The desert was alive: The Arabian peninsula was wet and fertile for several periods over the past 500,000 years. Finds of hand axes bear witness to the presence of human life there. Michael Petraglia (right) and his team study how even early humans altered the environment there.

enormous boulders and broke them into pieces. You can find tens of thousands of splinters there,” he adds.

Thus, according to Petraglia, humans started to change the Earth’s geology with the arrival of the first stone tools more than three million years ago: “Even the predecessors of modern humans shaped their environment.” However, the early traces of these changes are not always easy to identify, and the researchers in the Department of Archaeology at the Max Planck Institute in Jena have set themselves the task of tracking them down.

To be able to demonstrate the influence of humans on their environment in detail, they work closely with colleagues from the environmental sciences, including scientists from the Max Planck Institute for Biogeochemistry, which is also located in Jena. Through their collaboration, the archaeologists and environmental scien-

tists aim to understand how the spread of human beings altered landscapes, such as the tropical rain forest, affected animal and plant species, and even created entirely new ecosystems.

DEFINING THE ANTHROPOCENE SPARKS CONTROVERSY

“Archaeologists are aware that even those landscapes that seem pristine to us today were often changed by humans,” says Nicole Boivin, head of the new Department of Archaeology established at the Max Planck Institute for the Science of Human History last year. “Other disciplines are far less aware of this,” she adds, referring to a debate that recently flared up in the geosciences.

In August 2016, a working group of the International Commission on Stratigraphy announced that it would define a new geological epoch, the An-

thropocene, within the next three years. It argued that humanity has now become a “geological superpower” and has such a far-reaching influence on geological, biological and atmospheric processes on Earth that a new epoch needed to be defined.

But when did the Anthropocene start? The majority of the scientists in the working group are of the view that the beginning of this new age should be dated to 1950. New technologies that emerged in the mid-twentieth century left characteristic traces on the Earth from this point in time. For example, artificial radionuclides arose during nuclear bomb testing, and plastic and aluminum particles reached the environment for the first time and can be clearly detected in geological deposits. Other suggestions for the beginning of the Anthropocene include the year 1800 (the beginning of industrialization) and 1610 (argued to be



Pioneering work in the wilderness: While intensive research on the early history of Europe has been carried out for some time now, the Max Planck scientists in Saudi Arabia are truly breaking new ground with their work. With the help of satellite data, they focus their excavations on sites where rivers and lakes once existed.

the point at which the global exchange of plants and animals began).

However, as Nicole Boivin and three colleagues pointed out in a comment published in the journal *NATURE* in December 2016, the voice of the social sciences was missing from the debate. In particular, in the authors' opinion, the debate pays insufficient attention to archaeology, which, after all, has been exploring the influence of humans on the environment for a long time. According to their article, the formalization of the Anthropocene must be the product of a transparent, interdisciplinary discussion that should also involve the social sciences and humanities.

In the authors' view, in defining the new epoch, it makes no sense to refer to a single global event such as the beginning of above-ground nuclear tests. Instead, the significance of far-reaching social and ecological upheavals should

also be examined. "It's obvious that the changes happening today are on a far greater scale than ever before," says Nicole Boivin. "But human beings caused species to become extinct and fundamentally shaped landscapes in the past, too," she observes.

HUMAN IMPACT ON THE PLANET UNFOLDED IN FOUR PHASES

The quarries of *Homo erectus* on the Arabian Peninsula indicate that even these prehistoric humans shaped their environment – which at the time consisted of a savannah studded with lakes. As part of the "Palaeodeserts" interdisciplinary EU project, which started in 2012 and is headed by Michael Petraglia, researchers from Jena, the University of Oxford and other institutes have been studying precisely how environmental conditions in the Arabian Desert changed – and how this

shift between dry and wet conditions affected human settlement there. Conversely, humans are also likely to have left their mark on the environment – for example by hunting large animals such as elephants, hippopotamuses and antelopes. "They do not appear to have wiped them out completely," says Petraglia, "but an ecosystem changes even when a population isn't decimated by hunting."

Nonetheless, the changes initially remained more subtle, and are difficult to detect today. With the appearance of modern humans, *Homo sapiens*, the transformation of the planet picked up speed. Nicole Boivin points to four key phases of change: the spread of modern humans in the Late Pleistocene, which led to the extinction of many species; the development of arable and livestock farming, which led to the domestication of a range of species and resulted in the formation of entirely new



Prehistoric species extinction: Like the mammoth, many large animals all over the world became extinct after the last Ice Age. Their disappearance coincided with the spread of humans across the globe.

that can use new research methods to study complex questions that arise in several key areas. For example, it would be important to date individual events more accurately, to analyze old DNA and proteins, to create computer models, and to conduct paleoecological studies. A method known as ZooMS (Zooarchaeology by Mass Spectrometry) has lately proved particularly helpful in archaeological research, as it enables the identification of the species from which even gnawed, cooked and splintered bone remains originate based on collagen proteins.

"The megafauna are so important because their disappearance had dramatic consequences," explains Nicole Boivin. Giant herbivores such as mammoths are considered to be key species that can have a crucial impact on an ecosystem. They distribute nutrients and seeds over extensive areas and ensure that vegetation is kept in check. "When a species of this kind becomes extinct, the open landscape can become a forest. In extreme cases, if many large animal species disappear and forest regrows in extensive areas, this can even influence the global climate because carbon dioxide is removed from the atmosphere," says the Max Planck scientist.

It's difficult to pinpoint the extent of human influence on the environment at such an early stage, she notes.

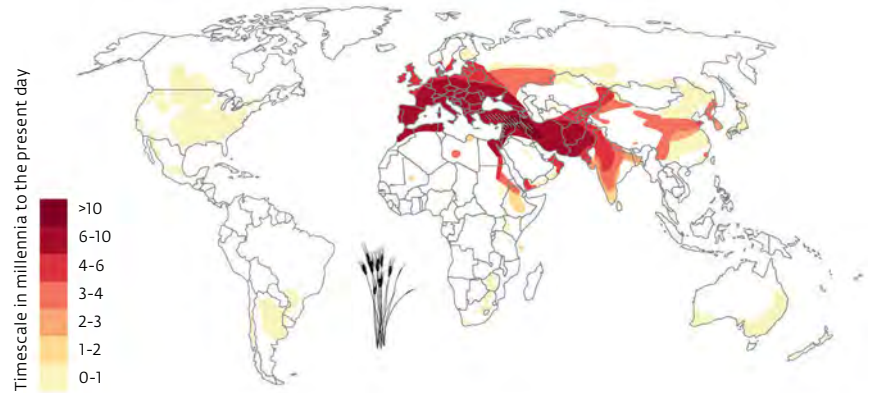
ecosystems; the settlement of remote islands where humans and their commensals often caused far-reaching changes; and finally, the growth of cities and development of trade networks, which resulted in the further intensification of agriculture, major land clearance, and the long-distance exchange of species.

MIGRANTS CREATED ECOLOGICAL NICHES

Homo sapiens arose some 195,000 years ago in East Africa and had settled in even the furthest reaches of Eurasia, Australia and America by around 12,000 years ago. This spread and the associated population growth changed the world: after the arrival of humans, some animal species disappeared, others were introduced to new areas and the settlers established new ecological niches for themselves that fulfilled their needs. For instance, humans started to burn gaps in the rain forest in New Guinea and Borneo to make way for the cultivation of starch-rich plants. In Australia and America, hunters set fire to the vegetation to attract wild an-

imals to the young plants that replaced it. Or they introduced potential game to areas where there had been little or nothing worth hunting before. The grey cuscus, for instance, a small marsupial from New Guinea, reached Indonesia, the Salomon Islands and the Bismarck Archipelago with the first settlers around 23,000 years ago.

The extinction of giant animal species known as megafauna is an interesting topic in this context. In the Upper Paleolithic period, that is, from 50,000 to 10,000 years ago, more than 100 out of 150 species of large animals weighing over 44 kilograms, such as the cave bear, the mammoth and the giant ground sloth, disappeared from the Earth. "Whether humans had something to do with this or whether climate, diseases or even meteorite impacts played a more important role is something that has been debated for decades," says Nicole Boivin. In February 2017, a two-day workshop was held at the Max Planck Institute for the Science of Human History in Jena with the aim of launching a major research project on this topic. It is Boivin's intention to assemble an interdisciplinary group

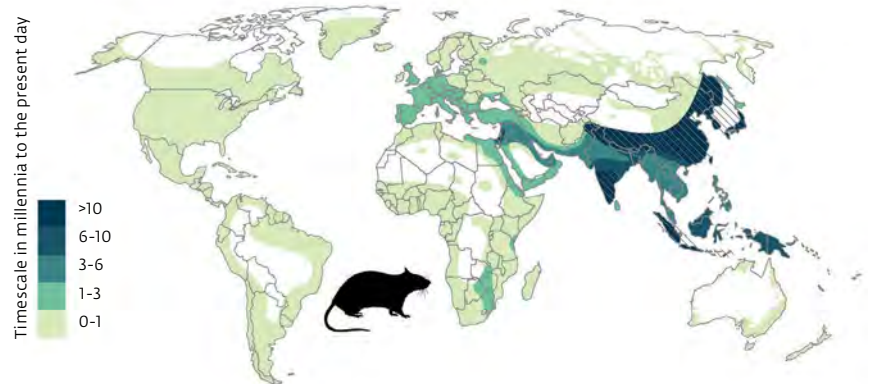
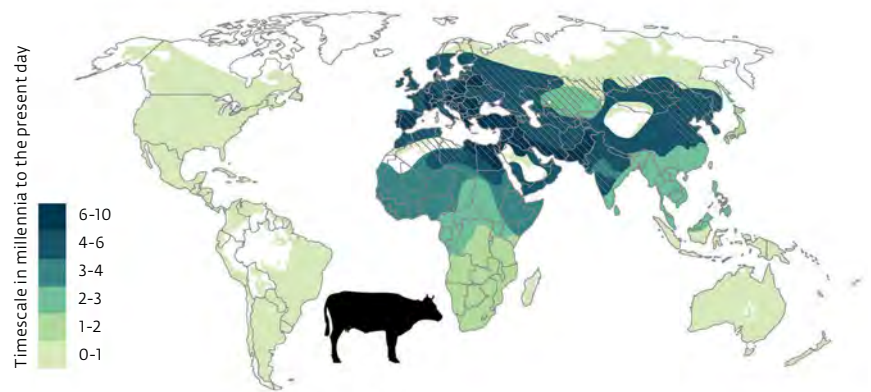


Moreover, influencing factors probably differed depending on the continent and latitude involved. The Jena-based archaeologist finds it intriguing, however, that the later *Homo sapiens* reached an area, the larger the number of animals that became extinct in the Late Pleistocene. “In Africa and India, the animals had, in some cases, millions of years to develop in parallel with the evolving skills of the humans,” she notes. When the first settlers reached Australia and South America, they already had advanced hunting techniques and better weapons at their disposal.

ANIMAL KINGDOM “NAIVE” IN NEWLY POPULATED AREAS

In regions more distant from Africa, the animal kingdom was probably still “naive” – with no fear of humans and unable to quickly adapt to the dangerous new enemy. The disappearance of the megafauna, which started around 50,000 years ago and is possibly the first human influence that can be detected in the ecological record, is one potential starting point for the Anthropocene.

According to the latest findings, humans also began to penetrate the rain forest around the same time, particularly in Southeast Asia. “Archaeologists had long assumed that the tropical rain forest represented an insurmountable barrier for early humans because it was too dark, too impenetrable and too dangerous, and moreover, it was not a good source of food,” says Patrick Roberts, head of the Stable Isotopes Re-



Plant and animal companions: Large numbers of individual species spread throughout the world in tandem with *Homo sapiens* – sometimes deliberately, sometimes accidentally. They include crops such as wheat (top) and domesticated animals such as cows (center), but also synanthropic species such as rats, which benefit from habitats created by humans (bottom).

search Group at the Max Planck Institute for the Science of Human History. However, it has now been demonstrated that the first hunters and gatherers were present in these ecosystems a good 45,000 years ago, for example in Borneo, Sri Lanka and New Guinea.

The Stone Age groups hunted a very wide range of animals and complemented their diet by collecting freshwater snails, nuts, fruits and roots. Roberts recently demonstrated that humans relied on the rain forest as a source of food in Sri Lanka many thousands of



Above Prehistoric plant remains are retrieved at an excavation site on the island of Unguja, which belongs to the Zanzibar archipelago off the coast of East Africa.

Below On the neighboring island of Pemba, Nicole Boivin's team found remains of an extinct or eradicated crocodile species.



years ago by testing the tooth enamel of human fossils. To do this, he determined the ratio of different carbon isotopes in human teeth originating from different sites in Sri Lanka, and was thus able to confirm the importance of the forest as a source of food.

Even these early inhabitants fundamentally altered the tropical forests, for example by setting fires and promoting the growth of certain plants. It would appear that tree species such as the Brazil nut, cocoa tree and cabbage palm dominate large swaths of the Amazon forest today because pre-Columbian groups deliberately cultivated them many thousands of years ago and spread their seeds. This was the finding of a study published in the journal *SCIENCE* in March 2017, in which Florian Wittmann from the Max Planck Institute for Chemistry in Mainz participated. The long-held view that rain forests such as the Amazon were pristine, ancient ecosystems is thus no longer valid. "In the Amazon, it's clear that hu-

mans interfered in the rainforest ecosystems prior to European colonization. There were even already cities there," says Patrick Roberts.

THE IMPACT ON ISLANDS IS PARTICULARLY EVIDENT

It's easier for archaeologists to detect the consequences of human settlement on islands than in impenetrable jungle areas. The first settlers didn't reach the remote archipelagos of the Indian and Pacific Oceans until a few thousand years ago – and their arrival often had devastating consequences. "We can see the impacts of this today wherever we take a more detailed look," says Nicole Boivin. "In New Zealand, for example, it took only a few decades after the arrival of humans for the forest cover to shrink considerably," says the Max Planck researcher. "Apparently-pristine tropical islands in the Pacific were altered dramatically well before Europeans arrived."

Photo: Mark Horton (top), Rainer Hutterer (bottom)

The Jena-based archaeologists are currently focusing on islands off the east coast of Africa: in the Zanzibar archipelago and the Comoros. Earlier excavations carried out by the team at the site of Kuumbi Cave in Zanzibar revealed that such animals as zebra, buffalo, waterbuck and gazelles disappeared when Zanzibar became an island. The promontory was connected to the mainland during the Ice Age and was separated from it only around 10,000 years ago when the sea level rose. It's still unclear whether these animals became extinct due to the reduction in habitat availability during island formation, or as a result of hunting or ecological alteration by humans.

"There are indications that the animals were hunted. We found projectile points, for example, and traces of cuts on some bones," reports Nicole Boivin. She and her colleagues are now in the process of providing a more accurate account of the ecological history of the islands in this region – an undertaking that arose out of the EU-funded "Sea-links" project, which was headed by Boivin and which examined the earliest trade relations between the cultures on the different coasts of the Indian Ocean.

The island of Pemba, the second-largest island of the Zanzibar archipelago, is also of interest to the Jena-based researchers in this context. It has been separated from the African mainland for millions of years. The first indications of human settlement there originate from the seventh century CE. In the past year, Boivin and her colleagues started excavating in a cave there and have accessed an environmental archive extending 5,000 years back into the past. Using molecular bi-

ological methods, her team helped demonstrate that crocodiles and giant rats existed on the island, but are extinct today. The team is currently examining the extent to which human beings altered other aspects of the island ecosystems.

The archaeologists are unanimous in their opinion that there is one conclusion that shouldn't be drawn from their research: that environmental, climate and species protection are unnecessary because humans have influenced the Earth since prehistoric times. "Even if completely pristine landscapes can no longer be found anywhere on Earth, protecting the environment is important," stresses Michael Petraglia. "We must learn to find a balance between the needs of humans and those of nature without causing too much damage to nature." ◀



Versatile researcher: Nicole Boivin is as well versed in biology as she is in archaeology. In her research, she traces the development and impacts of human life and activity from prehistoric times to the present day.

TO THE POINT

- Early humans left indelible traces on our planet even before the arrival of *Homo sapiens*.
- With the spread of modern humans, mammoths, cave bears and a large number of other species of megafauna went extinct.
- Through arable and livestock farming, humans created entirely new ecosystems and spread livestock and crops throughout the world.
- *Homo sapiens* left its traces for thousands of years, even in apparently untouched landscapes such as the Amazon rainforest.

GLOSSARY

Anthropocene: Suggested designation for a new geological epoch that is characterized by human influence on the biological, geological and atmospheric processes on our planet.

Megafauna: Animal species weighing more than 44 kilograms.

Paleoecological studies: Scientific studies of ecosystems from the Earth's geological past.