

ICY TIMES

TEXT: THOMAS TRAPPE

The last Ice Age has shaped human life in Europe for thousands of years. Driven from Central Europe by low temperatures during glacial periods, *Homo sapiens* repeatedly reconquered previously uninhabitable regions during interglacial periods. Johannes Krause and his team at the Max Planck Institute for Evolutionary Anthropology in Leipzig are studying these migrations.

Over 40,000 years ago, a hyena attacked and killed a woman and dragged her into a cave called Zlatý kůň near her home in the present-day Czech Republic. Her fate would have been forgotten, had archaeologists not discovered her remains in the middle of the 20th century. Bite marks on the bones attest to the drama to this day. The bones had lain largely unnoticed in an archaeological museum in Prague since the 1950s. Then, in 2021, they revealed a secret much bigger than the circumstances surrounding the victim's death: they provided evidence that modern humans must have come to Europe much earlier than previously assumed.

The find also revealed how difficult it was for *Homo sapiens* to permanently conquer a continent that yielded repeatedly to ice and snow. With the help of a discipline called archaeogenetics, researchers are able to analyze the genome of bones dating back thousands of years and recount the history of migration in Ice Age Europe. The resulting picture is of a continent in which Neanderthals and modern humans made repeated incursions, only to vanish time and again when the harsh climate proved too much for them.

Johannes Krause, 43, is one of the world's leading archaeogeneticists. As a doctoral researcher, he helped Svante Pääbo decode the Neanderthal genome, an achievement for which Pääbo received the 2022 Nobel Prize in Medicine. Since then, Krause has become the Director

of the Max Planck Institute for Evolutionary Anthropology. The work he contributed to has taught us much, including the certainty that all humans living outside present-day Southern Africa carry within them an average of two percent Neanderthal DNA. With the help of DNA from a tiny finger bone, Krause also managed during his postdoc with Svante Pääbo to discover the Denisovans, a hitherto unknown species of archaic human.

Cold and warm by turns

The results of archaeogenetic research show that it took modern humans multiple attempts to gain a permanent foothold in Europe. *Homo sapiens* migrated from the south to the north whenever the climate permitted.

“Anyone unable to cope with the new living conditions vanished.”

JOHANNES KRAUSE

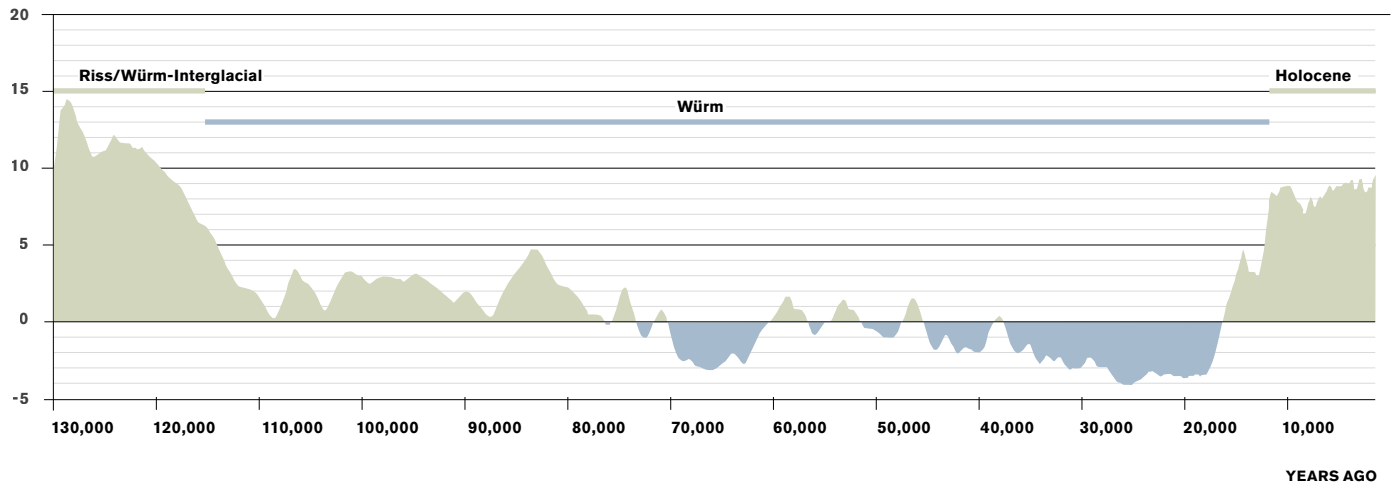
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Johannes Krause's research has made enormous contributions to our knowledge of early human history. Genes and the family relationships derived from them show scientists the migratory movements of Neanderthals and modern humans in the Ice Age.



PHOTO: SVEN DÖRING

TEMPERATURE CHANGE (IN °C)



Temperature changes in Antarctica, as reconstructed based on ice cores: Following the interglacial period from 130,000 to 115,000 years ago, termed the Riss-Würm Interglacial Stage in the Alpine region, temperatures dropped by more than ten degrees in Antarctica within 10,000 years. At the height of the glacial period 24,000 years ago, known as the Würm Ice Age in the Alpine region, temperatures fell by up to 4 degrees. A new interglacial period called the Holocene began 11,500 years ago and persists to this day.

And each migration was a new start. That's because the Pleistocene that began 2.5 million years ago and lasted until around 11,500 years ago was never consistently cold. Instead, the weather alternated between glacial (ice ages) and interglacial periods. These fluctuations arose due to changes in the Earth's orbit around the Sun, which changed the Earth's distance from the Sun and hence the global temperature. Average global temperatures at the height of several interglacial periods even exceeded present-day averages.

"The reality is that today we're only living in the interglacial period between ice ages," says Krause. Each climate shift also caused changes to flora and fauna. This often involved a radical disruption of natural resources, sometimes wiping out whole populations. To further complicate matters, *Homo sapiens* in Europe, western Central Asia, and the Middle East shared their habitat with another type of human: the Neanderthal. Before modern humans arrived in this region, Neanderthals had survived for around 400,000 years under a broad range of climate conditions, managing to make their way both in the cold steppes and in the forests of the interglacial periods.

The woman from Zlatý kůň cave is one of the earliest known modern humans (*Homo sapiens*) in Europe. Genetic analysis of her bones reveal that her ancestors must have arrived on the continent more than 45,000 years ago – at least 2000 years earlier than previous research had assumed. Clearly those humans were unable to gain a permanent foothold, as they left no traces in the genome of later human populations. Her

descendants must have died off at some point, bringing an end to the lineage from Zlatý kůň.

The re-dating of presumably the first wave of modern human migrants thanks to the find leads Krause to question an interpretation that remains common today, namely that *Homo sapiens* is responsible for the extinction of the Neanderthal around 39,000 years ago. "Both populations clearly lived alongside each other for thousands of years," says Krause. What is more, the two types of humans interbred, as evidenced by the presence of Neanderthal DNA in our genome today. Krause speculates that the disappearance of the Neanderthals and the first modern humans in Europe may be attributed in large part to a natural disaster: the eruption of a supervolcano. An eruption of the Phlegraean Fields near Vesuvius during that period hurled massive quantities of ash into the atmosphere and blotted out the Sun. Temperatures in large swaths of Europe and as far afield as present-day Russia dropped several degrees as a result. A shortage of light and a thick layer of ash might have stunted the growth of vegetation in large parts of Europe, depriving many animals of their food supply, including the Neanderthals and the descendants of the woman from Zlatý kůň cave. Furthermore, ashfall would probably have poisoned the drinking water in many areas.

"In my view, this volcanic eruption is the most convincing explanation for why not only Neanderthals, but also early modern humans disappeared during this period," explains Krause. *Homo sapiens* had a chance to resettle, however. Just a few years ago, Krause and his team examined human remains that had been found in Kostenki in western Russia. The analysis indicated that this individual had once been buried in the ashes of the Italian supervolcano, and hence must have lived



in the region after the eruption. The genetic traces obtained from the bones can be found in later Ice Age humans and even modern Europeans today.

The preconditions for resettling Europe were far from comfortable, as a new intense glacial period began more than 30,000 years ago. Survival became increasingly difficult for humans and animals. Genetic analysis shows that the population shrank massively in that period. This presented an opportunity for migrants who probably came from Eastern Europe. Specialists have named these and subsequent populations based on where they were found. Migrants from the east, for example, are called the Věstonice people after an archaeological site in the Czech Republic. In Central Europe they came across the Fournol, a group that at the time had resided primarily in Western Europe, as far south as the Iberian Peninsula. The Věstonice people had already developed techniques enabling them to hunt mammoths and other large mammals that had adapted to life on the cold steppes covering Central Europe more than 30,000 years ago, driving away animals native to Western and Central Europe. For example, the cave hyena, so deadly to humans, went extinct during this period. “What happened then is typical of the Ice Age as a whole,” explains Krause. “Climate fluctuations changed flora and fauna, and anyone unable to cope with the new living conditions vanished. That presented opportunities for better-adapted populations.” The glacial period reached its apex 24,000 years ago. Only a few plants and animals were still able to survive in Central Europe. Steadily advancing glaciers in Northern Europe and the Alps drove the Fournol people to the extreme southwest. During the coldest period, they found a homeland on the Iberian Peninsula with humans who already lived there, a region isolated from the rest of the continent by the glaciated Pyrenees. The Iberian refuge offered protection for thousands of years, while human life remained impossible elsewhere in Europe. People would not return to Central Europe until 5000 years later, or 19,000 years ago, when the glaciers finally began to thaw.

In March 2023, Krause’s team published evidence that, contrary to prior assumptions, there were no humans living in Italy at the height of the glacial period. Not until temperatures began to rise did modern humans migrate from the Balkan region along the Adriatic to present-day Italy. The forests thriving there offered the newcomers good living conditions. Today they are called Villabruna people.

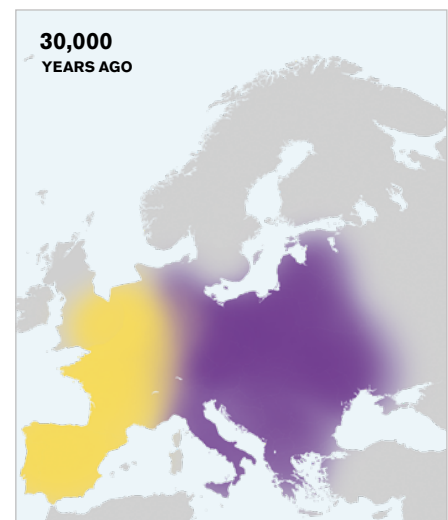
Around 14,500 years ago, an interglacial period lasting around 2000 years began. Temperatures rose quickly and the Villabruna people began to spread from Italy to large parts of Europe. They drove out the descendants of the Fournol people, who had survived south of the Pyrenees during the height of the last glacial period and had resettled Central Europe from there. The

SUMMARY

The first known migrants of the species *Homo sapiens* came to Europe 45,000 years ago. However, a volcanic eruption on the Italian Peninsula 39,000 years ago brought an end to this – until recently unknown – first settlement. The Neanderthals went extinct during this period as well.

Humans weathered the height of the last glacial period 24,000 years ago on the Iberian Peninsula and in the Balkans. Central Europe and the Italian Peninsula, by contrast, were unpopulated. With temperatures rising again, humans returned 19,000 years ago, setting out from the Iberian Peninsula. At around the same time, humans migrated from the Balkan region to present-day Italy. Descendants of those migrants spread out across Central Europe around 14,500 years ago and remain part of our genetic heritage to this day.

- FOURNOL
- VĚSTONICE
- GOYET Q2
- VILLABRUNA
- OBERKASSEL
- SIDELKINO
- DESCENDANTS OF FOURNOL



GRAPHIC: GCO BASED ON POSTH. C. YU. H., GHATLIGHI, A. ET AL. PALAEOGENOMICS OF UPPER PALAEOLITHIC TO NEOLITHIC EUROPEAN HUNTER-GATHERERS. NATURE 615, 117–126 (2023)

Fournol only managed to survive on the Iberian Peninsula. “We can still see traces of this upheaval today in the genome of people from that period.” Our analysis shows that the genes of humans coming from Italy dominated the genetic makeup of people in modern-day Germany, France, and Great Britain after only 500 years. The genes of what researchers refer to as Oberkassel people still comprise part of Europeans’ genetic heritage today.

“The climate shift 14,500 years ago probably played a decisive role in this wave of migration,” says Krause. As temperatures rose, forests pushed north, gradually replacing the steppe vegetation of the Ice Age. Smaller and faster forest animals required new hunting and gathering techniques, as well as knowledge regarding edible mushrooms and plants of the forest – skills mastered by the newcomers of Villabruna from their time on the already forested Italian Peninsula and Balkans.

Farmers from Anatolia

Next came farmers from Southern Anatolia, who migrated to most parts of Europe starting around 8000 years ago and interbred over time with the Indigenous Oberkassel people that still practiced hunting and gathering. Ötzi, for example, was a direct descendant of these migrants from Anatolia. This conclusion was reached in a study published by Krause and his team in 2023. The “Iceman,” who died in the high mountains over 5000 years ago, apparently belonged to a group living in extreme isolation

in the Alps, an exception to Europe’s settlement history. But the study didn’t stop with those migrants. Krause’s team discovered another component in the gene pool of modern Europeans: around 5000 years ago, members of a nomadic tribe arrived from the region north of the Black Sea. They must have quickly become the dominant group, as “steppe genes” still account for around 30 percent of the genetic makeup of many Europeans today. Did another drop in temperature occur? Or were the newcomers not peaceful migrants, but conquerors? There is no evidence for either claim. Instead, it may be that large swaths of Central Europe were devoid of people at the time. DNA traces of plague bacteria in bones from the period indicate that one of the first plague epidemics in history eradicated large parts of the population, clearing the way for the next wave of migration.

Even if climate had nothing to do with what seems to be the last large scale migration to Europe, it has exerted an enduring influence on the settlement of the continent for thousands of years. *Homo sapiens* was climate’s victim and beneficiary, by turns. Today, humans once again face decisive changes. Temperatures are rising faster than at any point in the past 10,000 years, which have seen the flowering of human culture. The cause is not variations in the Earth’s orbit, but large-scale emission of greenhouse gases. Instead of an ice age, humanity is now facing a heat age. Survival will become difficult if not impossible in many regions. And so climate will once again shape the migration history of humankind.

www.mpg.de/podcasts/kaelte (in German)

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Prehistoric DNA enables researchers to reconstruct the genealogy of modern humans in Europe. The populations named after archaeological sites were genetically separated from each other time and again. However, migratory movements repeatedly ensured that genes were exchanged (black arrow). Glacier coverage is depicted only at the time of maximum glaciation. The coast of Europe looked different during the last glacial period than it does today because the sea level of the Mediterranean was lower.

