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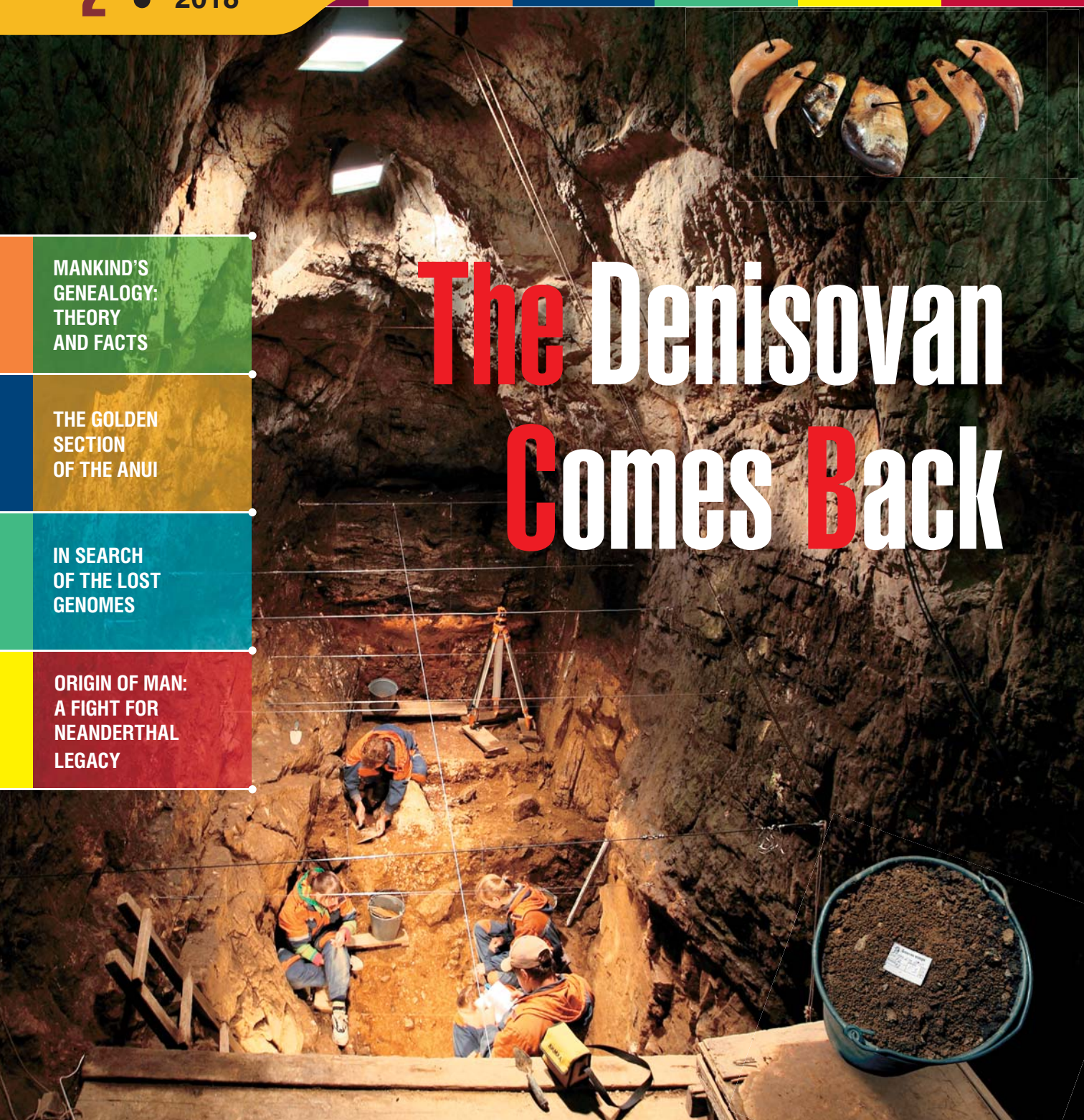

The Denisovan Comes Back

MANKIND'S GENEALOGY: THEORY AND FACTS

THE GOLDEN SECTION OF THE ANUI

IN SEARCH OF THE LOST GENOMES

ORIGIN OF MAN: A FIGHT FOR NEANDERTHAL LEGACY

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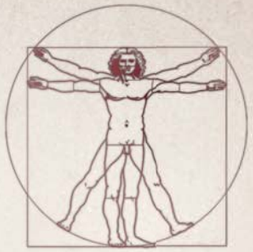

"The natural desire of good men is knowledge"
Leonardo da Vinci

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THE DENISOVAN COMES BACK

There was nothing special about this fragment of a fossil bone. Found in loose cave deposits alongside a multitude of animal bones, stone chips and artifacts, it was described, marked and packed as appropriate. Even after its "human" nature was established, it did not make the news although for the Denisova Cave anthropological material was a rarity. If this bone fragment had been found ten years earlier, it would have gone to a store-room of a research institute museum or become a modest exhibit marked "Homo sapiens." It was with this label that the future "star" arrived at Prof. S. Pääbo's laboratory. "In spring 2009 we received a bone fragment from Anatoly Derevyanko... The bone was tiny, and I didn't pay much attention to it thinking that when we have time, we'll analyze it for the presence of mitochondrial DNA (mtDNA). Possibly, if the bone appears to be Neanderthal, we'll be able to measure the degree of this DNA variability in the easternmost Neanderthals..." Today, this find is world famous – the primitive Denisovan girl has turned upside down our self-image just with her little finger

"Time will bring to light whatever is hidden."
Quintus Horatius Flaccus

There is hardly a single person who has never wondered how the first sensible human being appeared on our planet. By the way, according to recent surveys, almost half of the USA citizens and a fair share of Europeans cast a vote for the divine origin. Some of the respondents believe in extraterrestrial intervention.

However, the large community of scientists engaged in human origin and evolution was not unanimous in the interpretation of the enormous factual material accumulated since the late 19th century, when Pithecantropus erectus, the first candidate for the title of our ancestor, was discovered. The archaeological discoveries made in South Africa during the following century and results of the first genetic analysis of modern human populations proved just one thing: the ancestral home of all the mankind was Africa.

There is approximately three million years between modern humans and the most ancient Homo representatives; during that time humans not only acquired their present look but also settled all around the globe. Fossil anthropological remains and archaic tools of the oldest stone industries suggest three waves of the "Migration Period" from Africa to Eurasia. Scientists, however, are divided on the issue of what happened afterwards.

The monocentric theory shared by most scholars implies the explicit priority of Homo sapiens over his contemporary hominines, ultimately displaced by the superior species. Yet, this hypothesis fails to explain, among other things, why the Upper Paleolithic culture traditionally attributed to modern man sprang up virtually simultaneously in the regions of Eurasia very far apart. Another vital question is the principal differences of the stone industries of the early Upper Paleolithic implying at least the cultural continuity of the primitive population of each region.

Academician A. P. Derevyanko, upon the analysis of an immense body of archaeological data including the research results of the Paleolithic objects discovered during the expeditions organized by the Institute of Archaeology and Ethnography SB RAS in Central, North and East Asia, became a strong advocate of the multiregional concept of human origin. The most compelling arguments in its favor, however, relied on the extensive studies conducted for many years in Russian Altai, started at the time by an outstanding Soviet archaeologist and historian, Academician A. P. Okladnikov.

An interdisciplinary research into the Altaian Paleolithic has shown that the evolution of cultural traditions lasted there for at least 300,000 years (including the establishment of the Upper Paleolithic 50,000—40,000 years ago) without any noticeable signs of outside influences. And yet, what were they like, those people who made artifacts and

decorations typical of the early Upper Paleolithic before Europeans did it?

Regrettably, the Altaian Paleolithic was stingy with anthropological evidence, which, in addition, consisted of the rare findings of teeth and bone fragments not allowing restoration of the appearance of their owners. In 2005, A. P. Derevyanko wrote, "Our most optimistic expectations are to find in Altai a skeleton of the Paleolithic man. We have a couple of Paleolithic findings currently studied at the Max Planck Institute for Evolutionary Anthropology in Leipzig: some teeth and a bone fragment. But a complete skeleton is an archaeologist's fondest, albeit specific, dream." No complete skeleton of a fossil man has been discovered on Altai so far, and yet the reality has exceeded our grandest expectations. Owing to the multidisciplinary approach and international cooperation Siberian archaeology today is at the forefront of global science.

Firstly, the results of the decoding of the mitochondrial DNA extracted from the bone remains discovered in the Okladnikov and Denisova caves, conducted by S. Pääbo and his colleagues, became part of the evidence that "rehabilitated" Neanderthals, previously crossed out of the humankind's family tree. The most sensational result, though, was produced by the paleogenetic analysis of the little finger bone and a few teeth found in the Paleolithic deposits of the Denisova Cave. The analysis of both mitochondrial and nuclear genome has shown that the inhabitants of the cave, the so-called Denisovans, substantially differed both from the Neanderthals and modern humans.

Prof. Mikhail V. Shunkov and Prof. Anatoliy P. Derevyanko

The immense archaeological and anthropological material collected as well as the data of paleogenetic research suggest the existence of several large geographic zones based in Africa, East and South-East Asia, and in Europe, together with North and Central Asia, where the early forms of Homo sapiens – African, Oriental, Neanderthal, and Altaian – formed independently. All of them have contributed, albeit unevenly, in the formation of modern man.

Prof. Mikhail V. Shunkov,
Director of the Institute of Archaeology and Ethnography
of the Siberian Branch of the Russian Academy of Sciences

THE DENISOVAN COMES BACK

CONTENT

06 The Pleasure of Discovery, or a Hunt for Hominins

16 ***S. Pääbo***
In search of the lost genomes: from Neandertal – to Denisovan

32 ***M. V. Shunkov, A. P. Derevyanko***
Where has Homo Sapiens come From?

52 ***A. I. Krivoshapkin***
Origin of Man: A Fight for Neanderthal Legacy

62 ***M. V. Shunkov***
The Man's Family Tree has Branched Out

66 ***A. S. Pilipenko***
Ancient DNA Has Revealed Its Secret

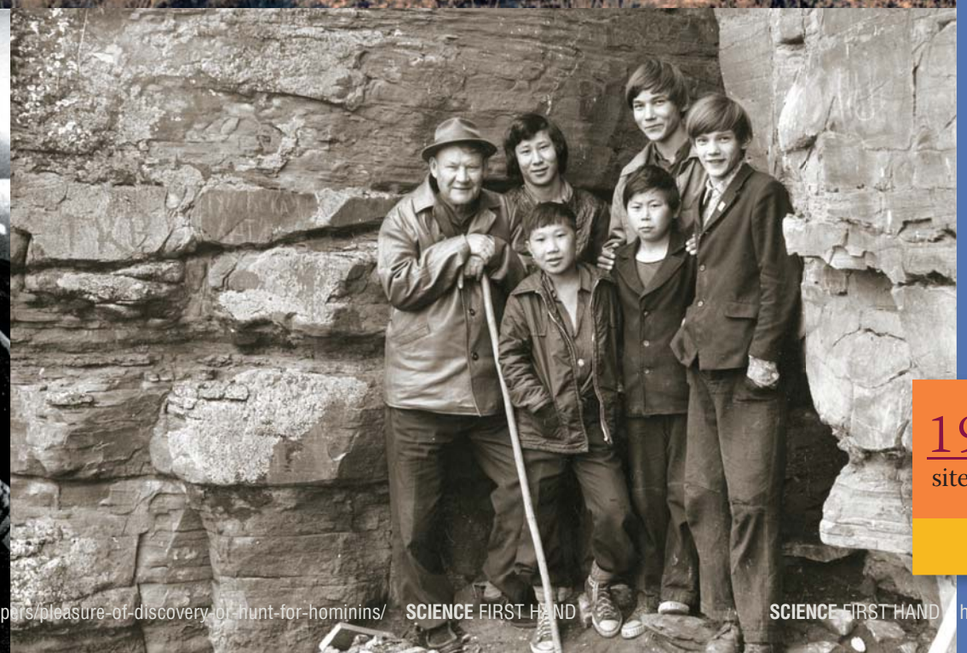
68 ***M. V. Shunkov***
The Denisova cave – Everything Changes, but Nothing Disappears

88 ***M. V. Shunkov***
The Golden Section of the Anui

The Pleasure OF DISCOVERY, or A HUNT FOR HOMININS

The material is based on the articles by Prof. Anatoliy P. Derevyanko and Prof. Mikhail V. Shun'kov, published in different years in SCIENCE First Hand

Anatoliy Derevyanko and Alexey Okladnikov in an expedition



Among the Shishkin rocks near Lake Baikal, with local boys, 1976. *V.P. Myl'nikov's archive*

When Alexey Pavlovich Okladnikov was asked what he valued most in life, he replied it was the pleasure of a new discovery. Recently I was asked a similar question, and I understood that no archaeologist can formulate the gist of our profession better. Certainly, big ideas do not spring out of nowhere, researchers come to them step by step. Any discovery requires numerous validations, which is the usual practice. When we go on expeditions, we do not seek for something absolutely unknown; normally, expeditions are preceded by thorough preparations, especially if the region is new for digging. We study geology, geomorphology, and natural conditions that existed there twenty thousand, two hundred thousand, or a million years ago… Today, discoveries rarely come as a surprise. What you don't expect is the quality of the discovery and a chain of related discoveries stemming from it.

Academician of the RAS Anatoliy P. Derevyanko

In the late 1930, an outstanding archaeologist, historian, and explorer Alexey Okladnikov made one of his sensational discoveries when he found the remains of a Neanderthal child in Teshik-Tash Cave (Uzbekistan). In spring 2017, a group of scientists from the Max Planck Institute for Evolutionary Anthropology, headed by Prof. Svante Pääbo, announced that they developed a method to retrieve hominin DNA from sediment samples collected in once-inhabited caves. What do these two events, separated by decades and thousands of miles, have in common?

The history of science knows no more alluring and controversial question, a question that would attract universal attention, than the origin of life and the evolution of man. The non-Biblical version of human origin is rooted in the hazy 1600s, when the works of the Italian philosopher Lucilio Vanini and the English lord, barrister and theologian Mathew Hale, with the speaking titles *On the Primitive Origin of Man* (1615) and *The Primitive Origin of Mankind, Considered and Examined According to the Light of Nature* (1671), were published. In summary, by the late 19th century, the idea of man as a product of a long evolution of more primitive anthropoid beings had germinated and ripened. Just one small thing was lacking – to discover this pithecantropos (from Greek pithekos "ape" and anthropos "man") "in flesh," which was done in the early 1890s by the Dutch anthropologist Eugene Dubois, who found the remains of a primitive hominin on the island of Java.

Since that time, another issue, as topical and controversial as man's descent from apelike ancestors, was placed on the agenda: geographical centers and development of anthropogenesis. Thanks to the amazing discoveries made in the recent decades by the cooperative efforts of archaeologists, anthropologists, and specialists in paleogenetics.

1990 Establishment of the archaeological site Denisova Cave

Key words: paleogenetics, mitochondrial DNA, nuclear DNA, hominid, Neanderthal, Denisovan

Until recently, it was only possible to determine DNA sequences and whole genome sequences from present-day individuals from which DNA can be isolated in good condition from fresh tissues such as blood. To evolutionary scientists this is somewhat frustrating because it represents an indirect way to study the past: one studies DNA sequences that exist today, uses the best models we have for how mutations accumulate and estimates what common ancestors may have looked like. This is frustrating because what we have are estimates subject to many uncertainties for example as a result of the mutational models used. However, by the end of the last century the breakneck development of molecular biology had given us methods for retrieving DNA sequences from archaeological and paleontological remains first of Late Pleistocene animals and then humans (Pääbo, 2014).

The first representative of archaic people that became known to science is the Neanderthal, *Homo neanderthalensis*. The Neanderthals mostly lived in Europe but traces of their presence have also been discovered in Near East, West and Central Asia and in the south of Siberia. These short stumpy people, physically strong and well adapted to the severe conditions of the northern latitudes, in terms of the brain volume were on a par with modern humans. In a century and a half that has passed since the first Neanderthals' remains were discovered, hundreds of their sites, settlements and burial grounds have been studied. It has turned out that these archaic people not only made quite advanced tools. According to Okladnikov, the excavations in Teshik-Tash Cave (Uzbekistan) "revealed an unpredicted, truly amazing picture, a picture no researcher had ever seen: the skull of a Mousterian man was circled, once in a strict order, clearly in accordance with a premeditated plan, with ibex horns. That arrangement provided compelling evidence of a rational mind, a logical plan of action, an entire world of ideas that stood behind that action."

No wonder that prior to the beginning of the 21st century, many anthropologists classified the Neanderthals as an ancestral form of modern humans; however, after mitochondrial DNA from their remains was examined, they were treated as a dead end. In 2007, Pääbo's laboratory investigated the mtDNA from the left femur of the Teshik-Tash Neanderthal child and from the bones found in Okladnikov Cave. Their comparison with earlier decoded genomes showed similarity between the Siberian and European Neanderthals.

The Neanderthals were considered to have been forced out and replaced by modern humans of African descent. Further studies have shown, however, that the relations between the Neanderthals and *Homo sapiens* were not as simple as that. Currently, there is no doubt that on the border of the areas populated by these humans not only cultural diffusion but also hybridization and assimilation took place. Today, the Neanderthals are classified as a sister group of modern humans, and their status of "man's ancestors" has been restored.

"One day, we may then be able to understand what set the replacement crowd (the 'new humans,' who replaced the archaic hominins – Translator's note) apart from their archaic contemporaries, and why, of all the primates, modern humans spread to all corners of the world and reshaped, both intentionally and unintentionally, the environment on a global scale. I am convinced that parts of the answers to this question, perhaps the greatest one in human history, lie hidden in the ancient genomes we have sequenced" (Pääbo, 2014)

Academician Anatoliy Derevyanko: "I wanted to be a journalist, but in 1961, I went in an expedition with Alexey Pavlovich Okladnikov and that was it: I became a fan of archaeology forever…"

on page 14

"Alexey Pavlovich Okladnikov never once vacationed at a health resort in his entire life, not because he was never sick. His whole life was his tireless labor – in the field, in the laboratory, at his desk. <…> When you read his works, you realize that the roots of his success lie in his deep respect and heartfelt care for the culture and history of the epochs and peoples, which seem to have vanished entirely off the face of the Earth. <…> Behind the so-called remnants of material culture, he saw, above all, a man endowed with a soul, thoughts, and feelings, a man who had been collecting, bit by bit, what we now call today."

From the book "Looking for a Golden-Horned Dear" by A. P. Derevyanko (1980)

Academician Alexey Okladnikov, the founder of research school for the history, archaeology, and ethnography of Siberia, the Far East, and Middle and Central Asia

A GIRL FROM THE STONE AGE

…All around us is the opulence the south. Even here, in this somber gorge, this land strikes with its lavishness. Opulence blooms everywhere: in colors, in aromas, in contrasts. Grapes ripen at the foot of the mountains; the never-melting snow blinds us with its dazzling glare from mountain tops.

The cave is dusky though it isn't deep. It descends 20 meters inside the mountain, and its ceiling is 7 to 8 meters high. It seems that enough light should be reaching its interiors. But the mountains… They obstruct the sun. Its rays seldom touch the cave floor. At first glance, it seems strange: Why would the primitive man avoid the sun? But in a moment, the sun rises in the east and ascends higher and higher up the sky. Finally, sunrays reach inside the cave, bringing life into it. Yes, the whole place revives from a huge mass of wasps and bees. Oh! The primitive man had thought about that when choosing a place to live.

<…> The cranium was lying with the crown down. It must have been crushed by a falling clot of earth. The skull was small! A boy's or a girl's.

With a spade and a brush, Okladnikov began widening the dig. The spade hit against something hard. A bone. Another one, and one more…It was a small skeleton, the skeleton of a child. An animal must have found its way into the cave and picked the bones. They were scattered, some of them gnawed and bitten. But when did this child live? In what years, centuries, millennia? If he was a young master of the cave when people who worked stone lived here … The thought was terrifying. If it was so, the child was Neanderthal. A man who lived tens of thousands or even a hundred thousand years ago. He must have a very pronounced brow ridge and no chin.

1939 Discovery of a Neanderthal burial in Teshik-Tash Cave

Teshik-Tash Cave.
Archive of the Institute of Material Culture History (St. Petersburg)

The easiest thing to do was to turn the cranium to have a better look but this would have disrupted the excavation plan. They had to complete the excavations around it leaving the child's bones untouched. The dig around them will deepen, and the bones will remain as though lying on a pedestal.

The archaeologist couldn't sleep that night. He thought about what may come out of that find and sneaked amazed glances at the workers who didn't sleep either. They sat around a fire, arguing… In the morning, Ikram said:

"They are leaving. Don't want to work here. They say: Muslims must not dig out the dead."

What will he do without the workers? If they go back to the *kishlak* [village], no one will ever come here.

<…> The *kolkhozniks* sat down in a circle, their deep, angry eyes piercing at Okladnikov.

He thought: What should he begin with? Should he tell them about the years of searching, about his struggle and determination, stunning to everyone in a man of his age? Tell them about his faith, fanatical faith, which, however, required proof? How he searched for this proof in taiga along the Lena River, near the desolate shores of the Angara, be it rain or heat? How they camped in tents, from the breaking of ice in spring to snowflakes in autumn, sleeping on frozen earth, about ice-cold rivers out of which you come stiff frozen, about clouds of mosquitoes, whose bites made your face burn, and you could barely speak, your eyes and lips swollen, but you couldn't hide from them. Against all odds – they marched further into the taiga, in search for answers, because they believed in the truth of history. In the truth without which people cannot live in this world yet which remains hidden in the millennia.

He looked at the workers around him. Grim faces, mistrustful eyes… They don't speak Russian. No, he must be brief. He must talk only about things that are familiar to them, things they'll understand.

Okladnikov shook his head, as he usually did when he took up on a hard business, and his stubborn curly hair pressed against his forehead.

"Long, very long ago lived a man. He was called a Neanderthal. We all come from this man. All people, no matter if their skin is white, or red, or black – all of us are equal, like brothers."

Okladnikov spoke slowly, so that Ikram could translate him. He saw the eyes of the Uzbeks grow warmer; they whispered to one another, shaking their heads approvingly. They were his friends, and he regretted he hadn't told them from the very beginning about himself, about Siberian peoples, about the amazing life of archaic humans, whose traces he had found in taiga. Those men became even closer to him: their fate had so much in common with that of Northern peoples.

"Now ask them: Do they agree to continue the excavations?"

<…> The *kolkhozniks* didn't sleep all night. They sat around the fire, drank green tea, sipping loudly, and argued.

A Neanderthal's skull. *Teshik-Tash, 1938. Archive of the Institute of Material Culture, St Petersburg*

In the morning, one of them, a tall, long-bearded man, packed his sack and walked down the hill, not looking back. The workers stared sullenly after him. Ikram dropped a word at him; everyone broke in laughter.

"I told them," he explained to Vera Dmitrievna, "that wasting words on a fool is like nailing a stone. They liked my words very much. They've changed completely after your husband's lecture."

Then he drawled pensively, looking at Okladnikov.

"In the hands of a true blacksmith, iron flows like water."

An excerpt from A. P. Okladnikov's journal. *Uzbekistan, 1938. St Petersburg Branch, Archive of the Russian Academy of Sciences*

The child's bones were left untouched. They were even covered. The archaeologists dug around them, and the bones were on a ground pedestal, which became higher every day. It appeared to be growing from the underground.

The night before that memorable day Okladnikov had trouble falling asleep. He was lying on his back, hands behind his head, looking up at the black southern sky. Far above, the stars were swarming. They were so many that it seemed there was not enough room for all of them. That faraway world inspired awe and at the same time instilled serenity. You felt like thinking of life, eternity, the faraway past and the faraway future.

What could the ancient man be thinking about when he was looking up at the sky? It was the same as it is now. Maybe, sometimes he also had trouble falling asleep, was lying in the cave and looking up at the sky. Did he only have memories or did he have dreams as well? What was that man? The stones told a story but there were many things about which they remained quiet.

Life buries its traces deep underground. Overlaying them are new traces, which with time also go down. And so it happens century after century, millennium after millennium. Life puts layers of its past in the ground. Paging through them, an archaeologist can learn about the doings of the people who used to live here and to determine, virtually without mistake, the times when they lived.

Drawing the curtain above the past, they removed land layer by layer, as time had put them."

Before starting the excavations, Okladnikov, as usual, dug out a test pit.

The pit revealed five cultural layers, i.e., five layers of earth retaining traces of man who lived there. The layers alternated with sterile ones, which deposited during the periods when man did not inhabit the cave.

Man came to this cave five times and left it five times. What made them leave? Giant catastrophes? The sterile layers contain silt and sand. There are boulders in the cave. Is this evidence of floods? Or, perhaps, man left the cave in search for better hunting grounds? Or a formidable enemy attacked people and forced them out of the cave? And then, again and again, man returned to these amazingly scenic places.

From the book "Along the path of faraway millennia"
by Ye. I. Derevyanko and A.B. Zakstelsky

2007 Study of the mtDNA from the left thigh bone of the Teshik-Tash Neanderthal

Prof. Mikhail Shun'kov,
Corresponding Member of the RAS,
Dr.-Sci. (History), Director
if the Institute of Archaeology
and Ethnography SB RAS
in Novosibirsk

The neighborhoods of Russia's largest archaeological stationary site Denisova Cave in the Altai Mountains house the most ancient settlement of primitive man in North and Central Asia—the Karama site, a remnant of the first migration wave from the African "cradle." Denisova Cave itself achieved worldwide fame after the recent discovery of a new, previously unknown representative of archaic mankind

The history of the Institute of Archaeology and Ethnography in Novosibirsk began from a standing commission to the Presidium of the Siberian Branch of the USSR Academy of Sciences at the end of 1958; its immediate predecessor was the Institute of History, Philology, and Philosophy SB USSR AS, established in 1966. The main organizer of the institute was Academician Alexey Okladnikov, a researcher with an enormous chronological, thematic, and geographical range. Serge Elisseeff, a professor at Sorbonne, once exclaimed in delight: "Okladnikov is a colossus of science!" Led forward by Okladnikov, researchers at the Novosibirsk institute set off to explore virtually all the epochs in the development of human society: from the early Stone Age to the late Middle Ages and the Modern Era. They rummaged large areas in North, Central, and East Asia to discover unique cave sites, primitive settlements, and rock images. Many of these finds and discoveries have become part of the treasure of Russian and world archaeology.

Okladnikov was succeeded at the director's post in 1983 by his student, a renowned expert in ancient history Anatoliy Derevyanko, who initiated a reorganization of humanities at Novosibirsk Science Center. Interdisciplinary studies of Asian antiquities in close cooperation with leading science centers of Russia, Europe, Asia, America, and Australia brought fundamental results, rated among the most outstanding achievements of modern archaeology.

Shun'kov, 2015

2008 Discovery of a finger phalanx of a Denisovan child

Many-meter-thick deposits in Denisova Cave retain traces of man's life from the Middle Paleolithic to Middle Ages

In the rest of Eurasia, the development of the Upper Paleolithic followed a different path. Let us trace this development through the example of the Altai region, which has produced some astonishing results obtained with the help of the paleogenetic examination of the anthropological findings from Denisova and Okladnikov caves. Paleogenetic studies confirmed that the remains discovered in Okladnikov Cave were Neanderthal whereas the results of the sequencing of mitochondrial and then nuclear DNA from the bone samples discovered in the occupation layer of the Upper Paleolithic early stage in Denisova Cave sprang a surprise on the researchers. The bone fragments proved to belong to a new fossil hominin, unknown to science, who was given the name of *Homo sapiens altaiensis*, or Denisovan, after the locality where he was discovered.

The genome of the Denisovans differs from the reference genome of a modern African by 11.7%, and that of the Neanderthal from Vindija Cave, Croatia, by 12.2%. This similarity testifies that the Neanderthals and Denisovans are sister groups with the same ancestor, who branched off the man's mainstream evolutionary trunk. These two groups separated approximately 640,000 years ago, taking the path of independent development.

Judging by the archaeological data, 50,000–40,000 years ago, in the northwestern region of Altai two different groups of primitive people lived next to each other: the Denisovans and the easternmost population of the Neanderthals, who came there at about the same time, probably from the territory of modern Uzbekistan. The roots of the culture whose carriers were the Denisovans can be traced back to the earliest sequences of Denisova Cave, as it was mentioned earlier. Interestingly, according to the panoply of archaeological findings reflecting the development of the Upper Paleolithic culture, the Denisovans were not only on a par with the anatomically modern humans inhabiting at that time other territories but in some respects were superior to them.

The discovery of the Denisovan, a new member of the hominin family, is of critical importance for modern science. For a long time, Siberian archaeologists believed that the population that inhabited South Siberia and created the earliest blade industry in Europe had been humans of a modern physical type. However, when the evidence for an unknown subspecies became compelling, scientists realized that the development of modern man followed a much more labyrinthine path than they previously thought. The hypothesis of a linear evolution of mankind, which prevailed in science until the late 1980s, clashed against the new data obtained by sequencing first the mitochondrial and then nuclear DNA and, finally, collapsed.

Based on the currently available archaeological, anthropological, and genetic materials from the most ancient sites in Africa and Eurasia, scientists now trace the origins of humans of a modern anatomical and genetic type, *Homo sapiens*, to at least four types of hominins: *Homo sapiens africaniensis* (East and South Africa), *Homo sapiens neanderthalensis* (Europe), *Homo sapiens orientalensis* (Southeast and East Asia) and *Homo sapiens altaiensis* (North and Central Asia). Evidently, not all of these subspecies have contributed equally to the formation of anatomically modern humans: *Homo sapiens africaniensis* featured the greatest genetic diversity, and it was he who laid the foundation for the modern human. However, the most recent data of paleogenetc research dealing with the presence of Neanderthal and Denisovan genes in the gene pool of modern mankind have shown that the other groups of ancient people did not stand back either.

2009 Study of the mtDNA from the phalanx of the Denisovan

Studying the cave soil. *The archaeological site Denisova Cave*

Huge prospects for further development of the theory of anthropogenesis come from a new paleogenetic method for retrieving traces of ancient people from sediments, which was developed by the international team led by Prof. Pääbo. As of today, researchers have found both Neanderthal and Denisovan DNA in soil samples from Denisova Cave; importantly, they have discovered it in the layers containing no fossil remains. This evidence suggests that archaic people had lived here tens of thousands of years earlier than we previously thought.

Skeletal fragments of archaic people are very rare archaeological finds, so the new way of working with fossil DNA will tell us much more about the time when they lived and about their place of living and migrations. Perhaps, we will even hunt down where exactly the Denisovans lived: an analysis of the genome of modern people indicates that they lived somewhere in Asia, but we yet have no clue as to where and when, and their remains have so far been found only in one place – in Denisova Cave.

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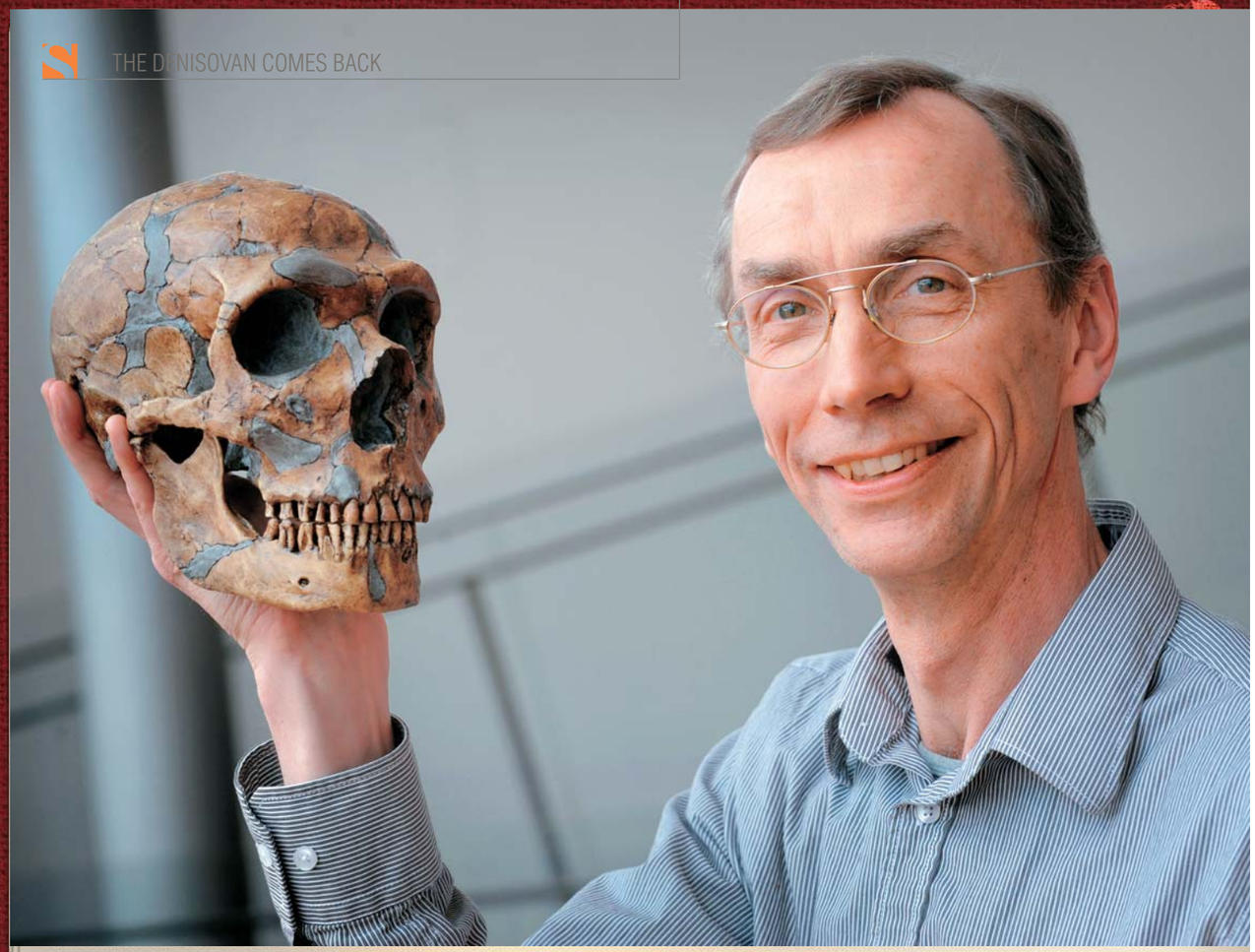

In search of the lost genomes: from Neandertal – to Denisovan

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Key words: paleogenetics, ancient DNA, nuclear DNA, mitochondrial DNA, genome sequencing, mutation, Neanderthal, Denisovan

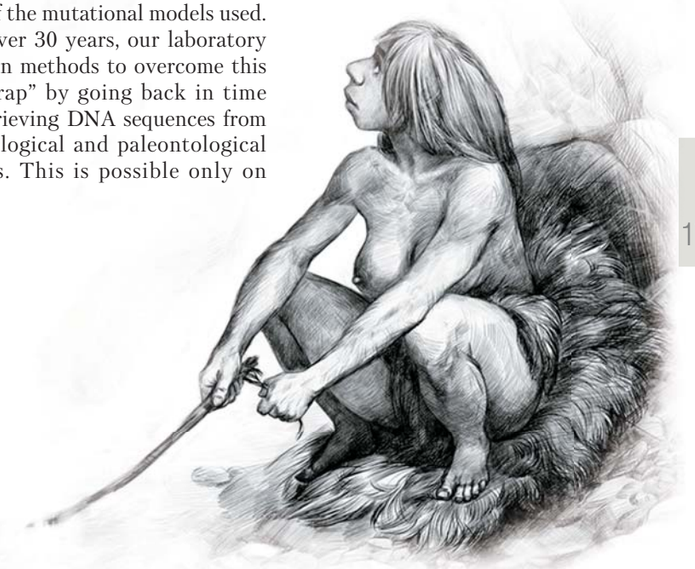
One day, we may then be able to understand what set the replacement crowd apart from their archaic contemporaries, and why, of all the primates, modem humans spread to all comers of the world and reshaped, both intentionally and unintentionally, the environment on a global scale. I am convinced that parts of the answers to this question, perhaps the greatest one in human history, lies hidden in the ancient genomes we have sequenced

The human genome is contained in chromosomes that are present in almost every cell in our bodies. It is composed of approximately 3,2 billion nucleotides. When cells replicate for form germ cell that will contribute to the next generation mutations occur. As a result of these mutations in the order of 50 to 200 new substitutions exist in every new individual that is born. These substitutions accumulate in the genome over time to the extent that roughly one nucleotide in a thousand differs between two human genomes today, whereas roughly one nucleotide in a hundred differ between a human and a chimpanzee genome. In addition, duplicated DNA sequences differ both between individuals and between species.

Each particular nucleotide site in the genome has its own history that could in principle be traced back through past generations. Such a history can be depicted in the form of a tree showing common ancestors shared with the same site seen in other individuals today. However, in reality, it is impossible to trace the history of a single nucleotide site. Therefore, one generally traces the average history of a segment of the genome, or the entire genome, and depicts that in the form of a tree that thus represents an average picture of how most sites in the DNA segments or genomes whose nucleotide sequences have been determined are related.

Until recently, it was only possible to determine DNA sequences and whole genome sequences from present-day individuals from which DNA can be isolated in good condition from fresh tissues such as blood. To evolutionary scientists this is somewhat frustrating because it represents an indirect way to study the past: one studies DNA sequences that exist today, uses the best models we have for how mutations accumulate and estimates what common ancestors in the past may have looked like. This is frustrating because what we have are estimates subjects to many uncertainties for example as a result of the mutational models used. Since over 30 years, our laboratory works on methods to overcome this "time trap" by going back in time and retrieving DNA sequences from archaeological and paleontological remains. This is possible only on rare occasions when well-preserved tissues can be found. Direct ancestors of present-day organisms are also almost never available. However, this approach nevertheless opens up new possibilities in that it allows DNA sequences from past populations and extinct species to be determined.

Of particular interest to us is the closest extinct relative of all present-day humans: the Neandertals. This robust form of hominins emerged in Europe and western Asia approximately 300,000 to 400,000 years ago and disappeared between 30,000 and 40,000 ago. The debate concerning the relationships between Neandertals and modern humans, and about what happened when they met, lasted for decades. One idea was that modern humans replaced Neandertals



IN SEARCH OF THE LOST GENOMES*

<…> In fact, there is ample evidence to suggest that genetic traits are a necessary foundation to these human behaviors. In the past, people sometimes did what we now consider to be unethical experiments in which they raised newborn apes together with their own children in their home. Although apes learned how to do many human-like things—they could construct simple two-word sentences, manipulate household appliances, use bicycles, and smoke cigarettes—they did not learn truly complex skills and they did not engage in communication on the scale that humans do. In essence, they did not become cognitively human. So it's clear that there is a biological substrate necessary for fully acquiring human culture.
This is not to say that genes alone are sufficient for acquiring human culture, only that they are a necessary' substrate. In the imaginary experiment where a human child is raised in the absence of any contact with other human beings, it is very likely that the child would never develop most of the cognitive traits that we associate with humans, including awareness of the interests of others. That unfortunate child would probably also not develop the most sophisticated of cultural traits that emanates from our tendency to share attention with others: language. So I am

**S. Pääbo «Neanderthal Man. In Search of Lost Genomes» (2014)*

without interbreeding, in which case the Neandertal contribution to present-day human genetic variation would be zero. Another idea was that Neandertal were the direct ancestors of Europeans. In this case, the Neandertal genetic contribution to present-day people in Europe would approach 100%. Obviously, all levels of contribution between 0% and 100% are also possible, and different levels of Neandertal contribution to present-day Europeans have been argued for on the basis of archaeological and paleontological data.

We got a first chance to directly test these hypotheses in the mid-90s when we were allowed to analyze the Neandertal bones that were discovered in the Neandertal Valley in Germany in 1856 and gave its name to this hominin group. At the time, we were able to draw on over ten years of experience with the development of techniques to extract and amplify small amounts of DNA from ancient remains of cave bears, mammoths and other late Pleistocene mammals (Pääbo, 2014). We focused on the mitochondrial DNA (mtDNA), because every cell contains hundreds or even thousands of mtDNA copies, making it easier to retrieve mtDNA than any particular part of the nuclear genome. We reconstructed the most variable part of the mtDNA and estimated phylogenetic trees to reconstruct the history of the mtDNAs of Neandertals and present-day people. In contrast to the nuclear genome, the mtDNA is inherited as one single unit from mothers to offspring without recombination so a phylogenetic tree for mtDNA reflects not the average history but the exact maternal lineages that relate the mtDNA analyzed. On the one hand these trees showed what was already know: that the mtDNAs of all people inhabiting the Earth today trace their ancestry back to a common ancestor about 100,000–200,000 years ago. But they also showed that the mtDNA lineage of the Neandertal type specimen went much further back in time and shared a common ancestor with present-day mtDNAs in the order of half a million years ago (Krings *et al.*, 1997). Subsequently, we and others have determined several other Neandertal mtDNA sequences. They all fall together outside the variation of the mtDNAs of present-day people. Thus, in 1997, it was clear that for the mtDNA, the complete replacement model held: no person today carries an mtDNA derived from a Neandertal.

However, the mtDNA represents only a tiny part of our total genome. The full picture of our genetic history can only be obtained by studying the nuclear genome. In the early years of this millennium it became feasible to consider sequencing genomes from ancient organisms thanks to new techniques that made it possible to sequence millions DNA molecules rapidly and inexpensively. We were lucky to receive funding from the Max Planck Society for a five-year effort to improve the technique of extraction of DNA from ancient bones and making DNA libraries that could be used for high-throughput DNA sequencing. We also analyzed a large number of bones from many sites in Europe to find those bones that contained the largest relative proportion of Neandertal DNA. We settled on a site in Croatia, from which we used tree bones from different Neandertal individual and sequenced more than one billion short DNA fragments extracted from the bones. We developed computer algorithms to match these short DNA sequences to the human genome while accounting for errors induced by chemical process that have affected them over tens of thousands of years. Only a few percent of all sequences derived from the Neandertal individuals. Nevertheless, in 2010 we were able to present about 3 billion nucleotides of Neandertal DNA that had been mapped to the human genome. Together these DNA fragments covered about 55% of the parts of the Neandertal genome to which short fragments can be mapped (Green *et al.*, 2010). This was enough to ask if any genetic interaction had occurred when modern humans encountered Neandertals.

If Neandertals made no genetic contribution to modern humans, the Neandertal genome would be equally far from Africans, Europeans and any other present-day populations. In contrast, if present-day Europeans carried DNA that they had inherited from Neandertals, European genomes would carry fewer differences to Neandertals than African genomes, since Neandertals were never in Africa so would not be expected to have contributed to genomes there. To test this, we sequenced the genomes of five present-day people and identified positions where two of these differed from each other. We then asked how often at these positions the Neandertal genome carried the variant seen in one present-day person and how often it carried the variant seen in the other present-day person. This approach of counting matches to pairs of present-day genomes was necessary since the quality of the Neandertal genome was so low that we could not trust

Many-meter-thick deposits in Denisova Cave retain traces of man's life from the Middle Paleolithic to Middle Ages

convinced that social input is necessary for the development of human cognition. However, no matter how early in life and how intensively they are integrated into human society and no matter how much teaching they are subject to, apes do not develop more than rudimentary cultural skills. Social training alone is not enough. A genetic readiness to acquire human culture is necessary. Similarly, I am convinced that a newborn human raised by chimpanzees would fail to become cognitively chimpanzee. There is surely also a genetic substrate necessary to becoming fully chimpanzee that humans lack. But since we are humans, we are more interested in what makes humans human than in what makes chimpanzees chimpanzee. We should not be ashamed of being "humancentric" in our interests. In fact, there is an objective reason to be so parochial. The reason is that humans, and not chimpanzees, have come to dominate much of the planet and the biosphere. We have done so because of the power of our culture and technology; these have allowed us to increase our numbers vastly, to colonize areas of the planet that otherwise would not have been habitable for us, and to have an impact on and even threaten aspects of the biosphere. Understanding what caused this unique development is one of the most fascinating, perhaps even one of the most pressing, problems that scientists face today. One key to the genetic underpinnings of this development may well be found through comparing the genomes of present-day humans with Neanderthals. Indeed, it is this feeling that kept me going during years of struggling with the technical minutiae of retrieving the Neanderthal genome.

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The dirty little secret of genomics is that we still know next to nothing about how a genome translates into the particularities of a living and breathing individual. If I sequenced my own genome and showed it to a geneticist, she would be able to say approximately where on the planet I or my ancestors came from by matching variants in my genome with the geographic patterns of variants across the globe. She would not, however, be able to tell whether I was smart or dumb, tall or short, or almost anything else that matters with respect to how I function as a human being. Indeed, despite the fact that most efforts to understand the genome have sprung from efforts to combat disease, for the vast majority of diseases, such as Alzheimer's, cancer, diabetes, or heart disease, our current understanding allows us only to assign vague probabilities to the likelihood that an individual will develop them. So in my realistic moments, I realized that we would not be able to directly identify the genetic underpinnings of the differences between Neanderthals and modem humans. There would be no smoking gun to be found.

Still, the Neanderthal genome was a tool that would allow us to begin to ask questions about what set Neanderthals and humans apart—a tool that not only we but all future generations of biologists and anthropologists would be able to use. The first step was obviously to make a catalog of all the genetic changes that happened in the ancestors of people living today after they separated from the ancestors of the Neanderthals. These changes would be many, and most of them would be without great consequences, but the crucial genetic events that we were interested in would be hidden among them.

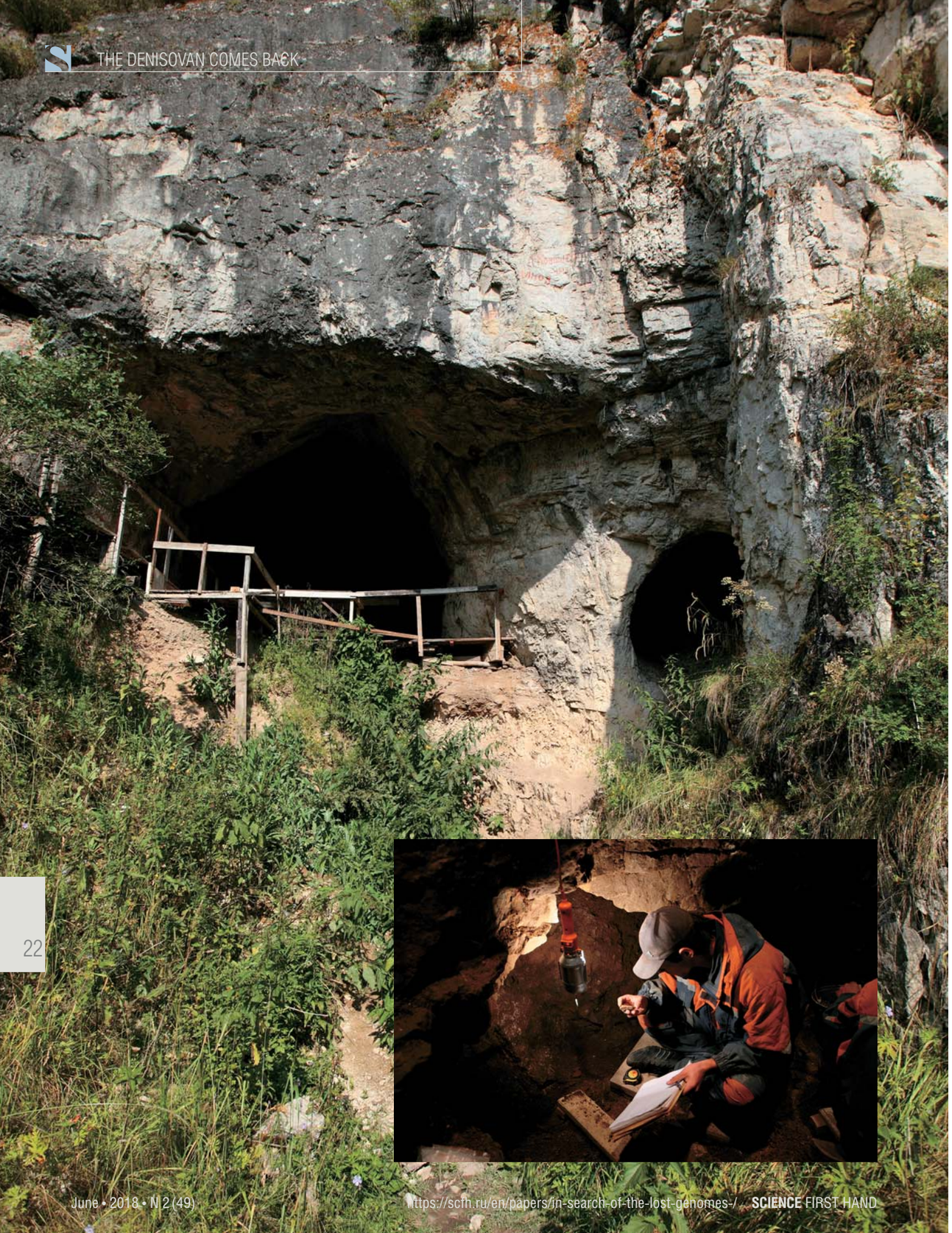
The crucial task of making the first version of such a catalog of all changes unique to modern humans was taken on by Martin Kircher together with his supervisor Janet

sequence variants that were seen only in the Neandertal genome and not also in one of the present-day genomes. When we compared two African genomes in this way the Neandertal genome matched variants in the two genomes equally often. This is to be expected since there was no reason to expect that Neandertals would have contributed DNA to the ancestors of any of the Africans. Intriguingly, when we compared a European and an African to the Neandertal genome we detected statistically significantly more matching to the European genome, suggesting that Neandertals had contributed DNA to the ancestor of the Europeans. Even more surprising was that when we compared a person from China to an African, and a person from Papua New Guinea to an African, we always found that the non-African matched the Neandertal genome more often than the African genome. This was surprising to us since Neandertals have probably never been in China and surely never in New Guinea. How could this be?

The explanation that we suggested and that has since been borne out by work in our own and other groups was that Neandertals met modern humans and mixed with them probably in the Middle East. If these modern humans later became the ancestors of everybody that today live outside Africa these early modern humans can so to speak have carried with them the Neandertal genetic contribution also to geographical areas where Neandertals never existed. As a result, between 1 and 2% of the genomes of every person whose roots are non-African is of Neandertal origin. That the Neandertal component in the genomes of present-day people has since been dated by studies of the extent to which Neandertal-like DNA segments have been broken down to smaller pieces by recombination that happens in each generation (Sankararaman *et al.*, 2012). It has also been confirmed by subsequent studies of a modern human that is about 40,000 years old who carries much larger segments of Neandertal DNA than present-day people since they lived much closer to the time of mixture (Fu *et al.*, 2014).

Of course, it is unlikely that mixing between Neandertals and modern humans happened only in one population and exclusively in the Middle East, but given the data at hand in 2010 this was the simplest explanation of our findings. Further insights were to a large extent limited by the comparatively low quality of the Neandertal genome. This was to be changed thanks to our collaboration with Anatoly Panteleevich Derevianko.

The excavations at Denisova Cave, led by Academician A. P. Derevianko and Professor M. V. Shunkov of the Institute of Archaeology and Ethnography of the Siberian Branch of the Russian Academy of Sciences have generated many fundamental and novel insights into human evolution. One of their crucial finds is a hominin toe bone discovered in 2010. When we applied new, ultra-sensitive methods that my laboratory have developed to extract DNA and produce



Denisova Cave is the most ancient Paleolithic site in Siberia. The first hominin appeared there 300,000 years ago

DNA libraries to this bone we were able to sequence almost 50-fold more endogenous DNA from this single small bone than from the three bones from Croatia that had been used to produce the first Neandertal genome a few year earlier. This individual turned out to be a Neandertal and its genome was sequenced to a quality higher than most genomes determined from present-day, living people (Prüfer *et al.*, 2014).

Using such high-quality genomic information, it is possible to observe differences between the two genomes that the individual inherited from her father and from her mother. One can thus gauge the extent of variation in the population where the parents of the individual lived. One can also estimate how closely related the mother and the father of the individual were to each other. In the case of the Neandertal from Denisova Cave this yielded an unexpected result. The paternal and maternal genomes had long segments of DNA that were identical. This means that the parents of this individual were closely related. One can estimate that they must have been related at the level of half siblings. When in the future further Neandertal genomes are sequenced to the same high quality as the one from Denisova Cave it will be interesting to see if this was an unusual situation among Neandertals or if it reflects social pattern typical of Neandertals.

The high quality of the Neandertal genome from Denisova Cave can also be used to estimate what parts of the genomes of present-day people were inherited from Neandertals. This confirms that everybody outside Sub-Saharan Africa carries between 1 to 2% of Neandertal DNA. This proportion is slightly larger in East Asia than in Europe, suggesting that additional admixture between

Kelso. Ideally, such a catalog should contain all genetic changes that are present today in all or nearly all humans and that occurred after modem humans parted ways with the ancestors of Neanderthals. The catalog should thus list positions in the genome where the Neanderthal looked like the chimpanzee and other apes while all humans, no matter where they lived on the planet, differed from the Neanderthals and the apes. However, in 2009 there were many limitations to how complete and correct such a catalog could be. First of all, we had sequenced only about 60 percent of the Neanderthal genome so the catalog could only be 60 percent complete. Second, even if we saw a difference from the human reference genome at a position where the Neanderthal genome looked like the chimpanzee genome, this did not necessarily mean that all humans today looked like the human reference genome. In fact, most such positions would vary among humans, but our knowledge about genetic variation among humans was too incomplete to differentiate real finds and false positives. Fortunately, there were several large projects under way aimed at describing the extent of genetic variation among humans, including the 1,000 Genomes Project, the goal of which was detecting all variants in the human genome present in 1 percent or more of humans. But that project was just starting. A third apparent limitation was that our genome was a composite of sequences from only three Neanderthals, and for most positions, we had only the sequence of a single Neanderthal individual. However, I didn't view this as overly problematic. As long as one single Neanderthal had the ape-like, ancestral version at a given position, it didn't matter if other Neanderthals that we hadn't sequenced carried the derived, new version that we saw in humans today. The knowledge that the ancestral variant was in at least one Neanderthal told us that it had still been around when Neanderthals and modem humans parted ways, perhaps 400,000 years ago. This made it a potential candidate for defining what might be universally modem human.

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Janet and Martin compared the human reference genome with the chimpanzee, orangutan, and macaque genomes and identified all positions where they differed. They then compared all four genomes to our Neanderthal DNA sequences, being careful to compare only those Neanderthal DNA sequences for which we had complete certainty as to where they came from in the genome. They found that we had Neanderthal sequence coverage for 3,202,190 positions where nucleotide changes had occurred on the human lineage. For the vast majority of these positions, the Neanderthals looked like us, which was not surprising, given that we are much more closely related to Neanderthals than to apes. But for 12.1 percent of these positions, the Neanderthal looked like the apes. They then checked whether the ancestral variants seen in apes and Neanderthals were still present in some humans today; in most cases they found both the ancestral and the new variants in present-day humans. This was not surprising because the mutations responsible happened quite recently. But some of these new variants were, as far as we could tell, present in all humans today. These were the positions that we found particularly interesting.

Detailed study of artifacts from the Denisova Cave under the leadership of Professor A.K. Agadjanian (The Institute of Paleontology RAS, Moscow)

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Clearly our paper was reaching a broader audience than we had ever imagined. But most people weren't shocked by the idea that their ancestors had interbred with Neanderthals. In fact, many seemed to find the idea intriguing—some, as had happened before, even volunteering to be examined for Neanderthal heritage. By early September, I started to notice a pattern: it was mostly men who wrote to me. I went back through my e-mails and found that forty-seven people had written to say they thought they were Neanderthals—and of these, forty-six were men! When I told my students, they suggested that perhaps men were more interested in genomic research than women. But that didn't seem to be the case, as twelve women had written to me not because they thought they were Neanderthals but because they thought their spouses were! Interestingly, not a single man had written to make such a claim about his wife (since then, however, one man has actually done so). I joked that some interesting genetic inheritance patterns were at work here that we needed to investigate. But what we were obviously seeing were the effects of the cultural ideas about what Neanderthals were like. In popular lore, Neanderthals are big, robust, muscular, somewhat crude, and perhaps a little simple. Some of these characteristics might be seen as acceptable or even positive in men, but they were clearly not conventionally seen as attractive in women. This idea was brought home to me when Playboy magazine called to ask for an interview about our work. I accepted, thinking that this would probably be my one and only chance to appeal- in *Playboy*. The magazine ended up writing a four-page story called "Neanderthal Love: Would You Sleep with This Woman?" The accompanying illustration was of a sturdy, very dirty woman wielding a spear on a snowy mountain ridge. That distinctly unattractive image probably explains why hardly any men volunteer the opinion that they are married to Neanderthals.
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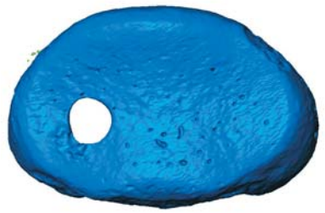
On December 3, 2009, I was attending a meeting on the rat genome at the Cold Spring Harbor Laboratory. I was there to describe a project on artificial

Neandertals and modern humans may have happened during the colonization of Asia (Vernot and Akey, 2015). To get a perspective on this, you may recall that we all have one half of our DNA from each of our parent, about 25% from each grandparent, about 12% from our great grandparents, and so on. From an ancestor six generations back we have on average inherited about 1.5% of our DNA. Thus, from the point of view of the total amount of DNA people today have inherited from Neandertals it is as they had a Neandertal ancestor six generations back. However, due to recombination that occurs when new germ cells are formed in each generation the Neandertal DNA is distributed in much smaller fragments than the DNA you have inherited from your ancestors six generations back. You may also ask how much of the total Neandertal genome exists distributed among people living today.

This estimate is still very approximate but it would seem that at least about 40% of the Neandertal genome can be found in people today.

Amazingly, the high-quality Neandertal genome is not the only great gift that Denisova Cave has given the world. In 2008 a tiny piece of the phalanx of a fifth finger of a child



Computer tomography of the finger phalanx that belonged to the Paleolithic man from Denisova Cave: the proximal, dorsal, and lateral projections, respectively

was discovered in the East gallery of the cave. We were privileged to work on this find and were happy to be able to generate first a low quality genome (Reich *et al.*, 2010) and then as our techniques improved a high-quality genome from it. In this genome each position in the part of the genome amenable to mapping short pieces of DNA was covered over 30 times (Meyer *et al.*, 2012). When we compared this genome to other genomes, we were surprised to find that it was neither a modern human nor a Neandertal. It shared a common ancestor with Neandertals but this ancestral population lived about four times further back in time than the oldest ancestral population shared among present-day human populations. After discussions with Academician A.P. Derevianko and his team in Novosibirsk, it was decided to name this new hominin group "Denisovans". It is the first hominin

domestication in rats that my group had been working on for the last few years. As I walked from the dining hall to the lecture hall after breakfast, my cell phone rang. It was Johannes Krause calling from Leipzig and he sounded strangely excited. I asked him what the matter was. He asked me if I was sitting down. When I said no, he said I'd better sit down before hearing what he had to tell me. Stalling to worry that something terrible had happened. I sat down.
He asked me if I remembered a small bone that we had gotten from Anatoly Derevianko in Russia. <…>
Some years previously, Anatoly had visited our laboratory and given us a few small bones in plastic bags. They had been excavated in a spot called Okladnikov Cave in the Altai Mountains in southern Siberia, where Russia, Kazakhstan, Mongolia, and China meet. These bones from Okladnikov Cave were too fragmentary to tell what type of human they had come from, but we extracted DNA from them and showed that they contained Neanderthal mtDNA. Together with Anatoly, we then published a paper in *Nature* in 2007 that extended the range where Neanderthals had lived by at least 2,000 kilometers further east of what had been commonly believed. Prior to our paper, no Neanderthal had been confirmed east of Uzbekistan.
In the spring of 2009 we received another bone fragment from Anatoly. His team had discovered that fragment during the previous year in Denisova Cave, another cave in the Altai region located in a valley that connects the Siberian steppes in the north to China and Mongolia in the south. The bone was minuscule, and I hadn't attached very much importance to it, thinking only that we would see whether it contained any DNA at some point in the future when there was time. Perhaps it would prove to be Neanderthal, which would enable us to gauge the extent of mtDNA variation among the easternmost Neanderthals.
Johannes had now found the time to extract DNA from the bone; and Qiaomei Fu, a talented young graduate student from China, had made a library and used a method that Adrian Briggs, the British graduate student in our lab. had developed to fish out mtDNA fragments from the library. They found a very large amount of mtDNA—in total 30,443 fragments, which enabled them to assemble

the complete mitochondrial genome with a very high degree of accuracy. In fact, each position in the mtDNA was seen an average of 156 times, unusually high for an old bone. That was good news, but it wasn't why Johannes asked me to sit down. He had compared the mtDNA sequence of the Denisova bone to the six complete Neanderthal mtDNA sequences that we had previously determined as well as to mtDNA sequences from present-day humans from around the world. Whereas the Neanderthals differed from modem humans at an average of 202 nucleotide positions, the Denisova individual differed at an average of 385 positions—almost twice as much! In a tree analysis, the Denisova mtDNA lineage branched off well before the modem human and Neanderthal lineages shared a common ancestor. When Johannes calibrated the rate of substitutions by assuming that humans and chimpanzees split 6 million years ago. then the Neanderthal mtDNA split from the human lineage about half a million years ago—just as we had previously shown—and the mtDNA of the Denisova bone branched off approximately 1 million years ago! I could hardly believe what Johannes was telling me. This was neither a modem human nor a Neanderthal! It was something else, entirely.

My head was spinning. What extinct human group could have split off from the human lineage a million years ago? *Homo erectus*? But the oldest *H. erectus* fossils outside Africa were found in Georgia and were about 1.9 million years old. So *H. erectus* were supposed to have left Africa and thus to have split from the lineage leading to present-day humans almost 2 million years ago. *Homo heidelbergensis*? But they were thought to be the direct ancestors of Neanderthals and would then presumably have diverged from the modem human lineage at the same time as Neanderthals. Was this bone from something totally unknown? A new form of extinct human? I asked Johannes to tell me everything about this bone. The bone was indeed tiny, the size of two grains of rice put together. It came from the last phalanx of the little finger, the outermost part of a pinky, from what was probably a young individual. Johannes had used a dentistry drill to remove thirty milligrams of material from the bone, and from this tiny amount of bone powder he had extracted the DNA that Qiaomei had used to make the library. Given how much mtDNA she and Johannes found, the DNA preservation in the bone must be exceptionally good. I would be back in Leipzig in three days and I told him that we would meet then and decide what to do. After I hung up, I couldn't bring myself to listen to presentations about how the genomes of different rat strains differed from each other. It was a sunny and snowless winter day in the New York area. I spent the morning walking along the windy beach below Cold Spring Harbor and thought about the young person who had died far away in a Siberian cave many thousands of years ago. All that remained of that life was a tiny speck of bone, but it was enough to tell us that she represented something unknown to us, a group of humans who had left Africa before the ancestors of the Neanderthals but after *Homo erectus*. Could we find out what this group was?

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As soon as we were back in Leipzig we finished the manuscript, which we entitled "The Complete mtDNA Genome of an Unknown Hominin from Southern Siberia," and sent it off to *Nature*. It was a unique paper. For the first time ever, a new form of extinct humans was described from DNA sequence data alone, in the total absence of any skeletal remains. Given that the mtDNA was so different from that of both modem humans and Neanderthals, we felt sure that we had found a new form of extinct human. In fact, we were so taken with this idea that, after some discussion, we decided to describe it as a new species, which we called *Homo altaiensis*.

However, I felt vaguely uneasy about suggesting a new species and soon had second thoughts. To me, taxonomy, the classification of living organisms into species, genera, orders, and so on, is a sterile academic exercise, particularly when discussing extinct human forms. Whenever my students send me manuscripts in which they use Linnaean Latin names for groups that are commonly known for example, "In order to better understand the pattern of genetic variation in *Pan troglodytes*, we sequenced…"

I always delete the Latin and sometimes even snidely ask who they are trying to impress by saying "*Pan troglodytes*" instead of "chimpanzees." Another reason I dislike taxonomy is that it has a tendency to elicit scientific debates that have no resolution. For example, if researchers refer to Neanderthals as "*Homo neanderthalensis*," they indicate that they regard them as a separate species, distinct from "*Homo sapiens*." This invariably infuriates multiregionalists, who see continuity from Neanderthals to present-day Europeans. If researchers say. "*Homo sapiens neanderthalensis*," they indicate that they see them as a subspecies, on par with "*Homo sapiens sapiens*." This invariably infuriates proponents of the strict out-of-Africa hypothesis. These arguments I prefer to avoid, and although we had by now shown (but not yet published) that there had been mixing between Neanderthals and modem humans. I knew that taxonomic wars over Neanderthal classification would continue, since there is no definition of a species perfectly describing the case. Many would say that a species is a group of organisms that can produce fertile offspring with each other and cannot do so with members of other groups. From that perspective we had shown that Neanderthals and modem humans were

Svante Pääbo visited the Geochronology of the Cenozoic Era Center for Collective Use (established with participation of Budker Institute of Nuclear Physics and Sobolev Institute of Geology and Mineralogy SB RAS)

group described on the basis of a genome sequence rather than a morphological description. Although remains of Denisovans have yet to be found outside of Denisova Cave, we can learn about their history and the history of other hominins by studies of their genome.

Interestingly, in the order of 5 % of the genomes of people that today live in the Pacific, for example Aboriginal Australians and Papuans, come from Denisovans (Reich *et al.*, 2011), suggesting the ancestors of these populations met Denisovans and sired offspring with them. In addition, about 0.2 % of the genomes of people in Mainland Asia come from Denisovans (Skoglund and Jakobsson, 2011; Prüfer *et al.*, 2014). By comparing the two high-quality genomes of a Neandertal and a Denisovan that have been determined from Denisova Cave we can also discern gene flow events that have occurred between these two groups and other gene flow events that have affected these two groups differently. A minimum of two additional instances of gene flow can be detected by these comparisons: one from eastern Neandertals into Denisovans, and one from an unknown hominin that diverged a million or more years ago from the human lineage into Denisovans (Prüfer *et al.*, 2014). In addition, recent work shows that early modern humans in Europe mixed with Neandertals when they first arrived there (Fu *et al.*, in press).

The emerging picture is thus a complicated one where many different hominin groups exchanged genes with each other on what must have been many occasions. Often this exchange was of limited magnitude but it shows that the gene pools of most or even all hominin groups in the Late Pleistocene were open systems that allowed genetic variants to spread from one group to the other. One interesting question then becomes of this may have been of functional importance. As yet, we do not know much about this, but I want to bring up a few examples of what has emerged from studies by several groups in the last two years.

One way to ask what functional role Neandertal genetic variants may play in present-day genomes is to ask what the genes are that carry Neandertal variants that have risen to high frequency. The fact that these variants have become frequent today may suggest that they were positively selected in the past. The group of genes that is statistically overrepresented in such genomic segments are keratins, i. e. structural protein in present in skin and hair (Vernot and Akey, 2014; Sankararaman *et al.*, 2014). Thus, it is likely that in the future we will find that some aspect of the morphology or function of skin and hair that is present in some people in Europe and Asia derive from Neandertals.

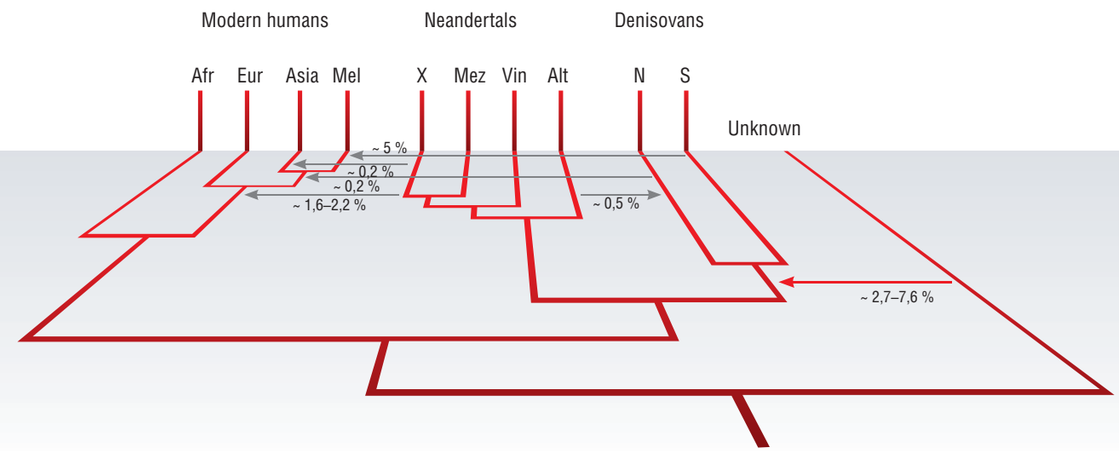
There are also aspects of metabolism that are affected by Neandertal variants. For example, Europeans but not in Asians carry more Neandertal variants than statistically expected of genes involved in the catabolism (Khrameeva *et al.*, 2014). It is not yet known what these variants do

the same species. However, this concept has its limitations. For example, polar bears and grizzlies can (and occasionally do) produce fertile offspring with each other when they meet in the wild. Yet polar bears and grizzlies look and behave differently, and are adapted to different lifestyles and environments. It would seem rather arbitrary, if not outright ridiculous, to regard them as one and the same species. We didn't know whether the fact that Neanderthals contributed perhaps 2 to 4 percent of the genes of many present-day humans meant that they were the same or different species. So it was ironic that, having always refrained from using a Latin name for Neanderthals in our papers, I was now on the verge of introducing a new Limiaean species designation myself.

Despite my misgivings about fruitless taxonomic debates, I felt I had some reasons for this digression from my principles. The mtDNA of the Denisova individual was about twice as different from the mtDNAs of modem humans as was the mtDNA of Neanderthals. That probably made them more like *H. heidelbergemis*, who did get to have their own Latin species name. But there was also vanity involved. Not many people get to name a new hominin species, which made it tempting to do so, even more so because this was the first time it would be done based solely on DNA data. However, the deciding argument came both from some people in our group and from Henry Gee at *Nature*. He pointed out that if we didn't take the initiative and give this hominin group a species name, someone else would. And that person might come up with a name we didn't like. So, after deliberating with Anatoly and the team who had excavated the crucial finger bone, we settled on provisionally naming it *Homo altaiensis*.

Nature kept its promise to process our paper quickly: eleven days after our submission, we received comments from four anonymous reviewers. They all praised the technical aspects of the paper but they were divided on the issue of naming a new species. Two reviewers voiced concerns that we might actually have sequenced a late *Homo erectus*. They felt that if *H. erectus* had had continuous contact with groups in Africa, they may not show an mtDNA divergence as deep as their first exit out of Africa some 2 million years ago. I doubted this. But the fourth reviewer made the point that saved us from ourselves. He or she said that "once a name is in the taxonomic literature, it cannot be withdrawn later. So such provisional naming is not wise, I believe." When I read this, I realized we had been foolish.

In the meantime, it dawned on us that the very large amounts of mtDNA that Johannes had been able to capture from the Denisova DNA libraries meant we would be able to sequence quite a bit of this individual's nuclear genome. This would settle its relationships both to Neanderthals and to modem humans in a definitive way as well as its possible status as a new species. We rewrote the manuscript and removed any reference to a new species. Instead, we said that "nuclear DNA sequences are needed to clarify definitively the relationship of the Denisova individual to present- day humans and Neanderthals." We sent it back to *Nature*, where it appeared in early April. As events would show, we had reason to be grateful that we had not named it a new species.



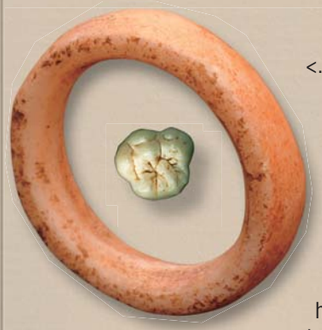
A schematic illustration of some archaic and modern groups and their genetic interactions. Modern humans are represented by African, European, Asian and Mleanesian populations; Neandertals are represented by an unknown population (X) contributing to non-Africans, and by Neandertal genomes from the Russian Caucasus (Mez), Croatia (Vin) and Denisova Cave (Alt); Denisovans are represented by an unknown population (S) contributing to people in the Pacific and by the population in the Altai Mountains (N). "Unknown" represents a hominin that diverged between one and four million years ago and contributed to the Denisovan genome. For each of the six genetic contributions detected to date, the approximate percentages of the genome contributed are indicated. *Prüfer et al., 2014*

but it will hopefully be discovered in the next few years. Interestingly, a variant if gene encoding a protein that transports lipids across cell membranes and is derived from Neandertals has risen to a frequency of up to 35% in East Asia and Native Americans. This variant is associated with increased risk to develop type 2 diabetes (SIGMA Consortium, 2014). It may seem surprising that a Neandertal gene variant that confers risk of disease has become frequent in the population. One may speculate that a variant that cause diabetes today in people who enjoy ample nutrition throughout life may have represented an advantage in a situation of food shortage. Thus, this gene variant may represent a Neandertal adaptation to starvation that in the past was advantageous also in modern humans.

Have Denisovans like the Neandertals contributed functionally to present-day people? Recent work suggests that this is the case. The population in Tibet carries genetic adaptations to life where the partial pressure of oxygen is low as is the case at high altitudes on the Tibetan High Plateau. The major gene variant responsible for this adaptation affects the number of red cells in blood and occurs at a frequency of about 80% in Tibet but is very rare elsewhere in Asia. Last year it was shown this gene variant is likely to be inherited from Denisovans (Huerta-Sánchez *et al.*, 2014). Thus, it seems that gene flow from Denisovans have contributed to making life at the high plateau in Tibet possible. Similarly, there are indications that gene variants important for how the immune system deals with infectious diseases may have been acquired both from Denisovans and from Neandertals (Abi-Rached *et al*, 2011).

There is thus a picture emerging where Denisovans, Neandertals and possibly other archaic groups who had lived in Eurasia for hundreds of thousands of years and had adapted to local environments met and mixed with modern humans on many occasions. This gave modern humans the opportunity to acquire locally advantageous gene variants from these groups. This is a phenomenon often referred to as "adaptive introgression" in other species (Hedrick, 2013) which may have been of some importance for modern humans as they colonized new environments throughout Eurasia (Racimo *et al.*, in press).

In summary, the fact that gene flow has been detected not only from Denisovans and Neandertals into modern humans but also between various other hominin groups shows that these were not closed genetic systems. They may best be regarded as a "metapopulation" – a web of populations that included Neandertals, Denisovans,



<…>

Monty Slatkin used all the DNA sequences we had generated to test various population models. As I expected, he found that the simplest model that explained all the data was admixture between Neanderthals and modem humans, followed by later admixture between Denisovans and Melanesian ancestors. But we still needed to explain the very strange Denisovan mtDNA. There were two possibilities. One was that the mtDNA lineage was introduced into Denisovan ancestors through admixture with another, more archaic hominin group. This was the idea I secretly favored. The other was that it was due to a process known as "incomplete lineage sorting." This means simply that the population that was the common ancestor of Denisovans and Neanderthals as well as modem humans carried earlier versions of all three mtDNAs. Then, by chance, one mtDNA variant that carried a lot of differences from the other two became the one that survived in Denisovans whereas the other two, which were much more similar to each other, became the ones that survived in Neanderthals and modem humans, respectively. This was particularly likely to have occurred if the ancestral population of Denisovans, Neanderthals, and modem humans was large enough that many mtDNA lineages could have coexisted in it. Monty's population models showed that the data could be explained either by a small amount of admixture from another unknown human group or by this "incomplete lineage sorting" scenario. Although that meant we couldn't favor one explanation over another, admixture nonetheless seemed a more plausible explanation to me. After all, we had already detected two cases of mixture between archaic groups and modem humans, so I had become much more open to the possibility that mixing was a common feature during human evolution. Furthermore, if the Denisovans were willing to have sex with modem humans, it seemed plausible that they would have sex with other archaic groups as well. I had come to believe that although the big picture of modem human spread was one where the replacement crowd pushed other groups into extinction, this was not a total replacement. Rather, some DNA seemed to leak over into the groups that lived on, so much so that I started using a term I had picked up from somewhere to describe this process: "leaky replacement." Perhaps, I thought, the spread of Denisovans had also been a "leaky" affair.

<…>

But even though we had sequenced the Neanderthal genome and opened the door to the genomes of other extinct human groups, many mysteries remained. One big mystery was when the Denisovans had lived. Both the finger bone fragment and the tooth were too small to allow- us to obtain radiocarbon dates. Instead, we had dated seven bone fragments, most with cut marks or other human modifications, found in the same layer in Denisova Cave. Four of the seven turned out to be older than 50,000 years, while three were between 16,000 and 30,000 years old. So it seemed there had been humans in the cave before 50,000 years ago and then again after 30,000 years ago. I tended to think that the older people were the Denisovans and the younger people modem humans, but we couldn't be sure. Professor Shunkov and Anatoly had found amazingly sophisticated stone tools and a polished stone bracelet in what seemed to be the same layer as the finger bone. Could they have been made by the Denisovans? It was an outlandish idea but the archaeologists felt it was possible.

Another big mystery was how far the Denisovans had ranged. We knew that they were in southern Siberia, but the fact that they had met and conceived children with the ancestors of Melanesians suggested that they had been much more widespread in the past. Perhaps they had roamed all over Southeast Asia, from temperate or even subarctic regions to the tropics. I thought we needed to look for Denisovan DNA in fossils from China. It would also be extremely exciting if Anatoly and his team could find more complete remains of Denisovans in the Altai Mountains. If those bones had features that set Denisovans apart from other hominin groups, these features would perhaps allow us to identify other fossils elsewhere in Asia as Denisovans.

My group and others have since gone on to work on these mysteries. Still other groups have begun to use ancient DNA to study past human epidemics and prehistoric civilizations. But that December I felt a satisfaction rare in my scientific career. What started as a secret hobby when I was a graduate student in my native Sweden over thirty years ago had resulted in a project that seemed like science fiction when we announced it a little over four years earlier. We had now brought this project to a successful conclusion. With my family in our cozy little Swedish hut. I was more relaxed over those Christmas holidays than I had been for a long time.

modern humans and other groups, which were linked by but intermittent or sometimes perhaps even persistent gene flow (Pääbo, in press). In this metapopulation gene variants spread directly, but also potentially indirectly between groups who were in contact with each other over other groups.

These results support the idea expressed by Academician Derevianko already in 2005 when he said "Dear colleagues, please do not offend Neanderthals.

They are among our ancestors!" (Derevianko, 2005). The analyses of the genomes from Denisova Cave have shown that this generous attitude was correct and should be extended to Denisovans and perhaps also other hominin forms.

Acknowledgements. Our work is made possible by the long-standing, fruitful and stimulating collaboration with Academician Derevianko and Prof. Shunkov who lead the work at Densiova Cave. I am also indebted to past and present members of our research team and collaborators who have made the analyses of archaic genomes possible; to the Max Planck Society for continuous support and to the Russian Academy of Sciences for its support of the important work in Siberia and for the honor bestowed upon me today.

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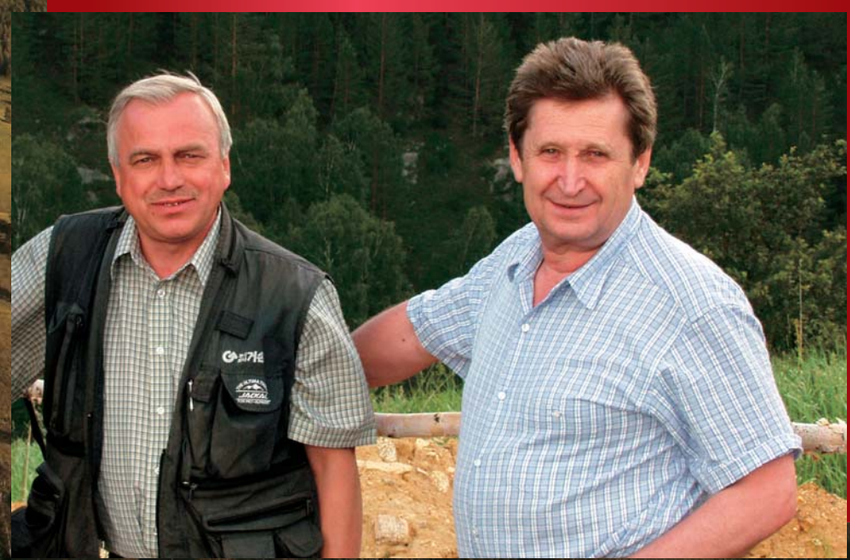
A.P. DEREVYANKO, M.V. SHUNKOV

WHERE HAS Homo Sapiens COME FROM?

We – people – are so different! Black, yellow and white, tall and short, dark-haired and fair-haired, brilliant and not very bright… Yet all of us – a blue-eyed Scandinavian giant, a dark-skinned pigmy from the Andaman Islands, and a tawny nomad from the African Sahara – belong to the same and sole mankind. And this is not a poetic figure of speech but a fact established by science and supported by the latest research in molecular biology. But where shall we look for the source of this many-faced living ocean? When, where and how did the first human being appear on the earth? Amazingly, even in our enlightened time, almost half citizens of the USA and a large share of Europeans vote for the divine origin, and many of the others believe in extraterrestrial interference, which, in fact, is not too different from the Divine Providence. However, even a firm advocate of evolution cannot give an unambiguous answer to this question



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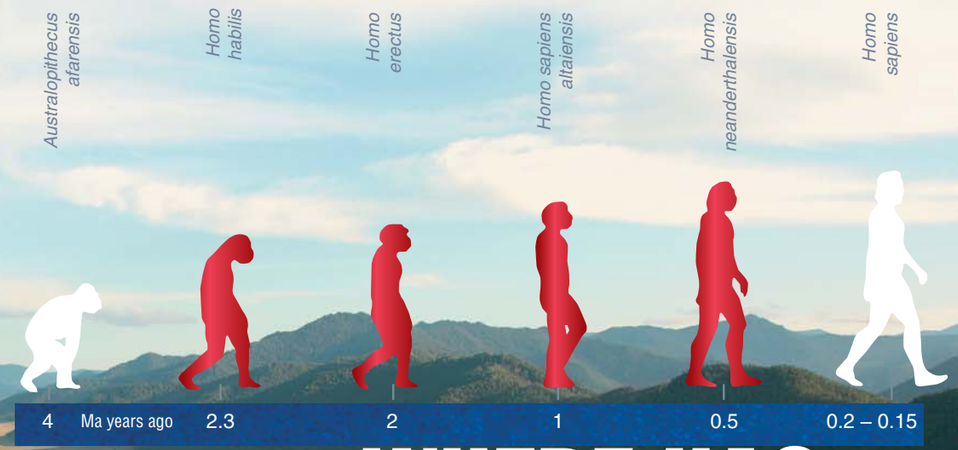
Key words:
paleogenetics, mitochondrial DNA, nuclear DNA, hominines, Neanderthal, Denisovan



Numerous traces of the early man were discovered in Kazakhstan and Central Asia. In particular, on the dry eastern coast of the Caspian Sea, tens of thousands of primitive stone tools were found: in the Mugodzhar Hills alone (top), dozens of ancient hand axes – bifaces – can be collected on an area of one square meter

Unfailing outcrops of flint on the eastern Caspian coast were an attractive source of raw materials for making stone tools

"A man has no reason to be ashamed of having an ape for his grandfather. If there was an ancestor whom I should feel shame in recalling it would rather be a man — a man of restless and versatile intellect — who not content with an equivocal success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance."

Thomas Huxley (1869)

Not everybody knows that the non-Biblical version of human origin is rooted in the hazy 1600s, when the works of the Italian philosopher Lucilio Vanini and the English lord, barrister and theologian Mathew Hale, with the speaking titles *On the Primitive Origin of Man* (1615) and *The Primitive Origin of Mankind, Considered and Examined According to the Light of Nature* (1671), were published.

The baton passed by the philosophers who acknowledged the kinship of humans and apes was taken up in the 18th c. by the French diplomat B. de Mallier, and then by James Burnett, Lord Monboddo, who put forward the idea of the common descent of all the anthropoids, including man and chimpanzee. The French naturalist Georges-Louis Leclerc, Comte de Buffon, in his voluminous *Histoire Naturelle*, published a century before Ch. Darwin's scientific bestseller *The Descent of Man and Selection in Relation to Sex* (1871), boldly asserted that man had originated from an ape.

In summary, by the late 19th century, the idea of man as a product of a long evolution of more primitive anthropoid beings had germinated and ripened. Moreover, in 1863 the German biologist and evolutionist Ernst Haeckel even classified the hypothetical being, the intermediate link between man and the ape, as Pithecanthropus alatus, i.e., an ape-human devoid of speech (from the Greek *pinthecos*, ape, and *anthropos*, man). Just one small thing was lacking – to discover this pithecantropos "in flesh," which was done in the early 1890s by the Dutch anthropologist Eugene Dubois, who found the remains of a primitive hominin on the island of Java.

Since that time, the planet Earth has been recognized as an official place of residence of the early man, and another issue, as topical and controversial as man's descent from apelike ancestors, was placed on the agenda: geographical centers and development of anthropogenesis. Thanks to the amazing discoveries made in the recent decades by the cooperative efforts of archaeologists, anthropologists, and specialists in paleogenetics, the problem of the development of the modern human, like in the days of Darwin, has generated a lot of public interest and moved beyond mere scientific debates.

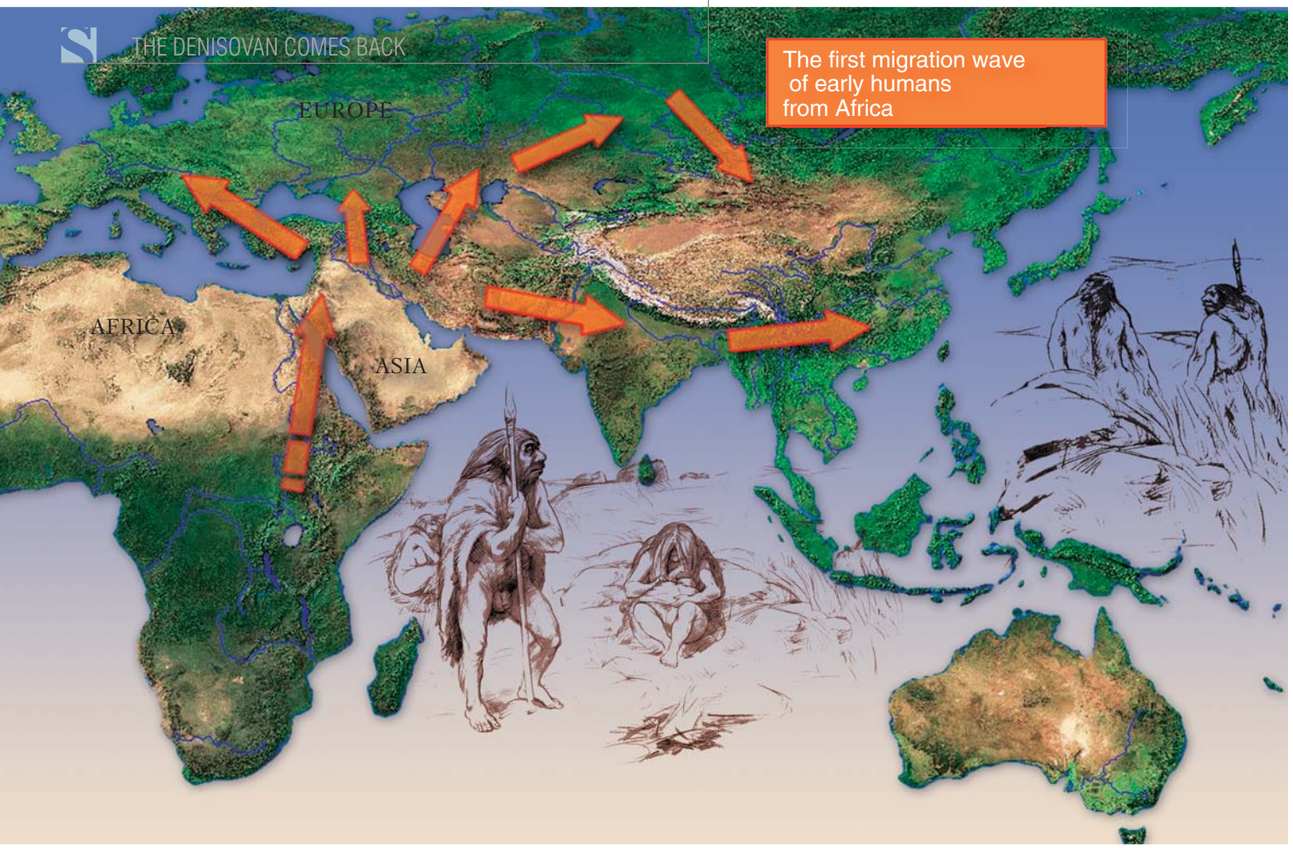
African cradle

The history of the search for the ancestral homeland of the modern human, a plot with many twists full of astonishing discoveries, looked at first like a list of anthropological findings. In the first place, natural scientists became interested in the Asian continent including Southeast Asia, where Dubois discovered the osseous remains of the first hominin, later called Homo erectus. Then, in the 1920s—1930s, archaeologists found numerous fragments of the skeletons of 44 individuals who lived in Zhoukoudian Cave in Northern China, Central Asia, 460,000—230,000 years ago. These people, referred as Sinanthropuses, were once considered the oldest link in human genealogy.

Gradually, however, Africa pretended to the title of "mankind's cradle." In 1925, in the Kalahari Desert, the fossil remains of a hominin called Australopithecus were discovered; in subsequent 80 years, hundreds of similar remains, aged from 1.5 to 7 million years, were found in the south and east of the continent.

In the Great Rift Valley, running from the Dead Sea depression through the Red Sea and on through Ethiopia, Kenya and Tanzania, more ancient sites were discovered with stone artifacts of the Oldowan Industry (choppers, choppings, roughly retouched flakes, etc). Excavations

In the history of science you can hardly find a more exciting and controversial problem that would stir up common interest than the problem of life origin and development of its intellectual peak – humanity



About two million years ago, Homo erectus left Africa and began to settle in Eurasia. It was the first wave of the oldest migrations of man

in the basin of the Kada Gona river led to the discovery, under a layer of tuff 2.6 Ma old, of more than 3000 primitive stone tools made by the first representative of the Homo genus - *Homo habilis*.

Mankind has become much older – it became evident that at least 6–7 Ma ago the common evolution tree split into two separate branches: anthropoid apes and Australopithecus, and the latter marked the beginning of the new, "sensible," development path. The world's oldest fossil remains of modern people – Homo sapiens, who appeared about 200,000–150,000 years ago – were also discovered in Africa. In this way, by the 1990s, the Recent African origin model, supported by recent genetic studies of various human populations, became universally accepted.

However, in between the two extreme reference points – the most ancient ancestors of humans and modern mankind – there is at least six million years during which the man not only developed his present look but also occupied virtually the whole territory of the planet fit for living. If Homo sapiens first appeared only in the African part of the world, when and how did he settle on the other continents?

Three exoduses

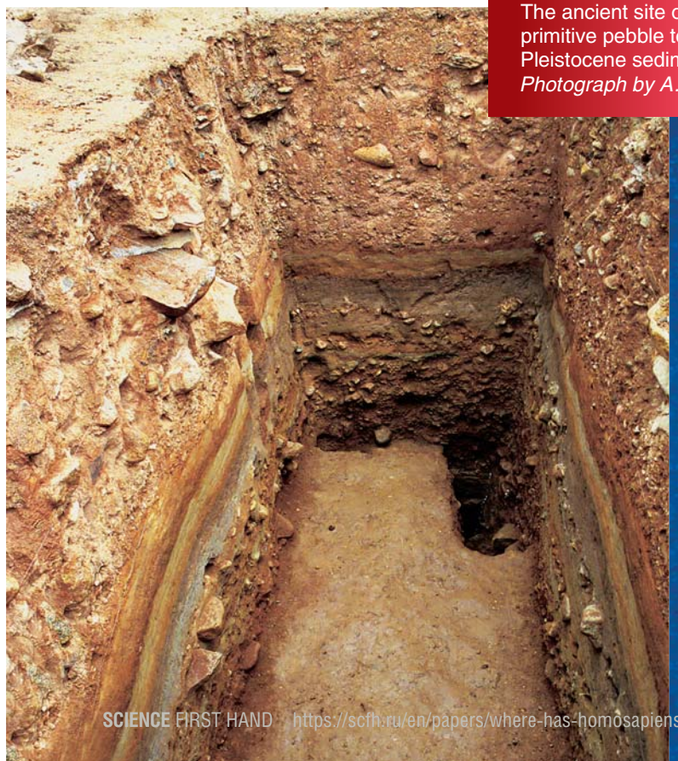
About 1.8–2.0 Ma years ago, the ancient ancestor of modern humans – *Homo erectus* or close to it *Homo ergaster* – first left Africa and began his conquest of Eurasia. This was the beginning of the first Migration Period, a long gradual process that took hundreds of millenniums and which can be traced by the fossil remains and typical tools of ancient stone industry.

The first migration flow of the oldest populations of hominins branched into two main directions, northward and eastward. The former went through the Near East and Iranian Plateau towards the Caucasus (and, probably, Asia Minor) and on to Europe. This is evidenced by the oldest Paleolithic localities in Dmanisi, East Georgia, and Atapuerca, Spain, dated 1.7–1.6 and 1.2–1.1 Ma, respectively.

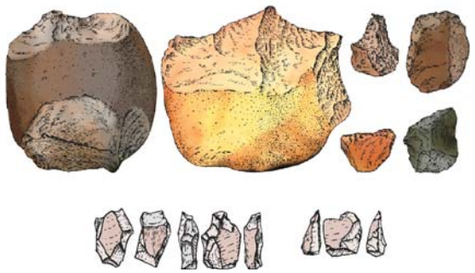
In the east, an early testimony of human presence is pebble tools dated 1.65–1.35 Ma, found in the caves of South Arabia. Further migration to the east took two paths: the northern way went to Central, and the southern way went to East and Southeast Asia across the territory of modern Pakistan and India. Judging by the dating of the deposits of quarzitic tools in Pakistan (1.9 Ma) and China (1.8–1.5 Ma) and of the anthropological findings in Indonesia (1.8–1.6 Ma), the early hominins settled on the expanses of South, Southeast and East Asia not later than 1.5 million years ago. On the border of Central and North Asia, in Altai, South Siberia, an early Paleolithic Karama site was discovered – its deposits contained four layers with an archaic pebble industry aged 800,000–600,000 years.

All the oldest sites of Eurasia left by the first wave migration had pebble tools characteristic of the most ancient Oldowan Industry. About the same time or a little later, representatives of other early hominines came from Africa to Eurasia. They were carriers of a microlithic stone industry, where small tools dominated, and they took virtually the same ways as their predecessors. These two oldest technologies of stone working played the key role in the development of ancient tool making.

The second global wave of African migration spread to Near East about 1.5 Ma ago. Who were these new migrants? Probably, *Homo heidelbergensis* – a new type of people that combined both Neanderthal and sapiental



The ancient site of Karama in the Altai Mountains: primitive pebble tools discovered in multilayered Pleistocene sediments.
Photograph by A. Postny and S. Zelenskiy



So far, not many osseous remains of primitive humans have been found. The bulk of material accessible to archaeologists is stone tools. From them, they can trace how the stone working techniques improved and human intellectual abilities developed

features. A distinguishing feature of "new Africans" was stone tools of Acheulean industry made using more advanced stone working technologies – the so-called Levallois technique of stone knapping and methods for bilateral working of stone on both sides. Moving to the east, this wave met the descendants of the first wave hominines, which involved a mix of the two industries, pebble tool and Late Acheulean.

Approximately 600,000 years ago, these migrants of African descent reached Europe, where the Neanderthals – the type closest to modern humans – later developed. About 450,000—350,000 years ago, the bearers of Acheulean tradition penetrated the east of Eurasia, reaching India and Central Mongolia but they did not go as far as the eastern and southeastern regions of Asia.

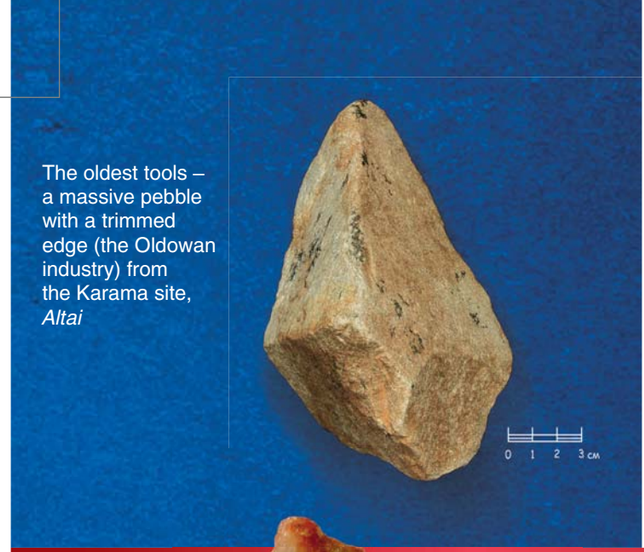
The third exodus from Africa is related to the anatomically modern humans, who came to the evolutionary arena 200,000—150,000 years ago, as it was mentioned earlier. It is supposed that about 80,000—60,000 years ago, Homo sapiens, traditionally believed to be the bearer of Upper Paleolithic culture, began settling on other continents: first in the eastern part of Eurasia and Australia and then, in Central Asia and Europe.

Now we have approached the most dramatic and controversial part of our story. Genetic research has proved that all modern mankind descends from the same species of Homo sapiens, provided that mythical creatures like Yeti are disregarded. Then what happened to ancient human populations, descendants of the first and second migration waves from Africa, who lived in Eurasia for tens or even hundreds of thousands of years? Did they leave a trace in the evolutionary history of our species and if yes, how important was their contribution to modern humanity?

Depending on the answer to this question researchers can be divided in two groups, monocentrists and polycentrists.

Two models of anthropogenesis

In the end of the last century, the monocentric point of view on the appearance of *Homo sapiens* ultimately prevailed – the hypothesis of the African "exodus," according to which the only ancestral home of *Homo sapiens* is the "black continent," from where he settled all around the world. Basing on the results of the study of genetic variability of modern people, its advocates suppose that 80,000—60,000 years ago there was a demographic explosion in Africa, and as a result of a sharp growth in the population and lack of food, a new migration wave swept over Eurasia. Failing to withstand competition with a more evolutionarily advanced species, other hominines existing at that time, such as the Neanderthals, fell out of the evolutionary race some 30,000 – 25,000 years ago.

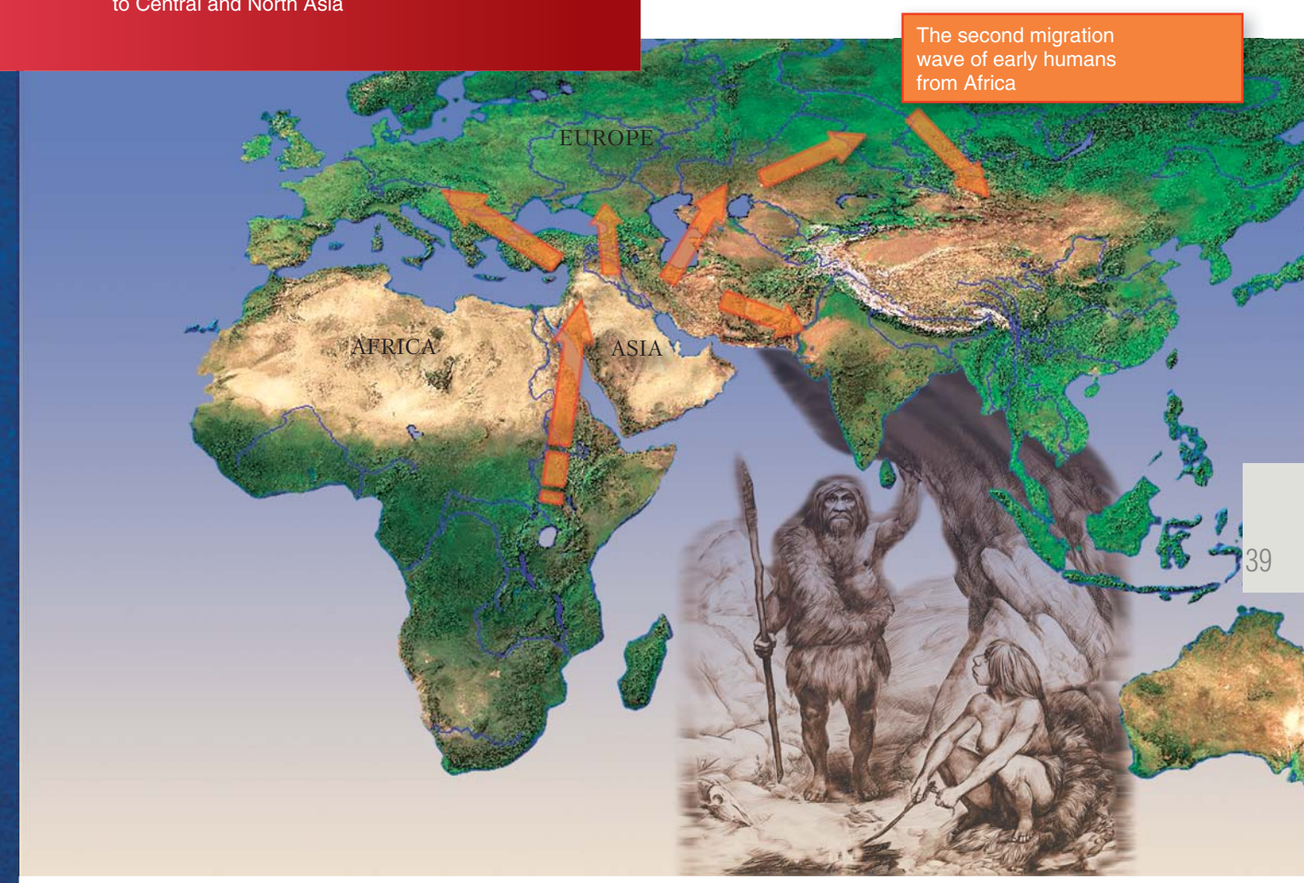


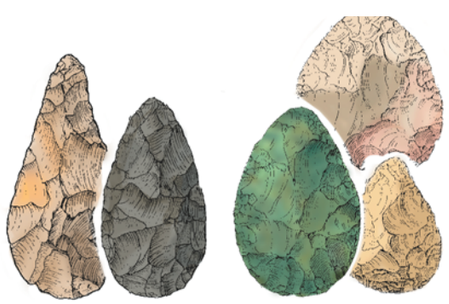
The oldest tools – a massive pebble with a trimmed edge (the Oldowan industry) from the Karama site, *Altai*

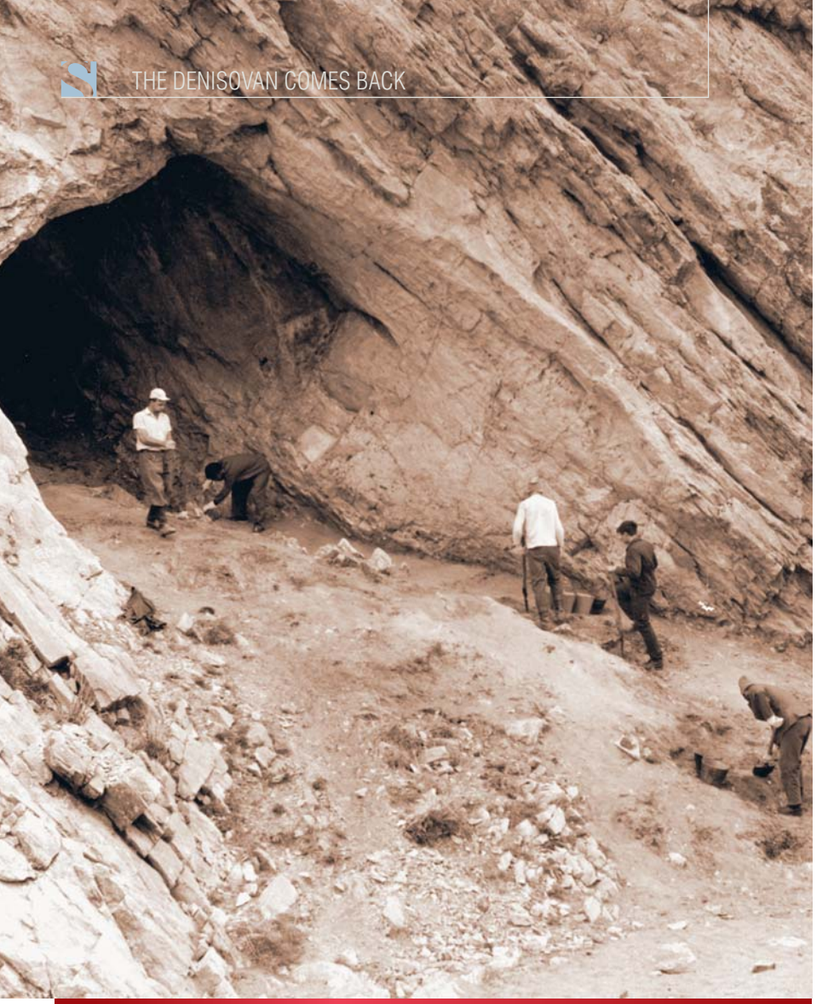
Samples of a microlithic industry aged 600,000—800,000 years, the Darvagchai river, *Dagestan*

Stone tools of the more advanced Acheulian industry (bifically worked tools) from the Tsagan-Agui cave, *Mongolia*

The second wave of the earliest migrants from Africa moved eastwards through the western regions of Asia. They are supposed to have taken two ways: one to the south of the Himalayas and Tibetan Plateau through Hindustan to East and Southeast Asia, and the other through the West Asian Uplands to Central and North Asia







The *Tsagan-Agui* cave in Gobi Altai is among the few well-dated Mongolian archaeological monuments; it contains the remains of the cultures of all Paleolithic stages and of later epochs

Monocentrists have a variety of opinions on the progress of this process. Some believe that the new human populations exterminated or drove out the aboriginal populations to less comfortable regions, where their mortality grew, especially among children, and their birthrate dropped. Others do not rule out the possibility of occasionally long coexistence of the Neanderthals and modern humans (for example, in the southern Pyrenees), which could result in cultural diffusion and at times hybridization. According to the third point of view, acculturation and assimilation took place whereby the aboriginal population dissolved among the newcomers.

It is difficult to fully accept all these circumstances without convincing archaeological and anthropological evidence to support them. Even if we agree with the debatable presumption that the population grew very quickly, it is inexplicable why the migration flow did not spread initially across the nearby areas but went a long way off to the east, reaching Australia. As an aside comment, though Homo sapiens must have covered a distance of over 10,000 kilometers, so far no archaeological evidence has been discovered to prove it. Moreover, archaeological data suggest that in the period from 80,000 to 30,000 years ago no change occurred in the local stone industries of South, Southeast and East Asia, which should have happened in the event the newcomers actually replaced the aborigines.

This absence of "road" proofs has led to the version that *Homo sapiens* moved from Africa to the east of Asia along the sea coastline, which today is under the water together with all Paleolithic evidence. If this is true, however, African stone industry must have been almost the same on the islands of South-East Asia, while archaeological materials aged 60,000—30,000 years do not support this idea.

Today, the monocentric hypothesis has given no satisfactory answers to many other questions either. In particular, why did anatomically modern humans appear at least 150,000 years ago and the Upper Paleolithic culture, traditionally connected exclusively with *Homo sapiens*, almost 100,000 years later? Why this culture, which emerged virtually simultaneously in far-away regions of Eurasia, is not as homogenous as it should be expected in the case of a single carrier?

These "dark spots" in man's history may be accounted for by another, polycentric concept. According to this hypothesis of interregional human evolution, *Homo sapiens* could develop both in Africa and on the vast expanses of Eurasia, inhabited at that time by *Homo erectus*. It is the continuous development of the ancient population in each region that explains, in the polycentrists' opinion, the striking difference between the Upper Paleolithic cultures of Africa, Europe, East Asia and Australia. Even though from the standpoint of up-to-date biology the formation of the same species (strictly speaking) in such different and geographically remote areas is unlikely, it is possible that independent, parallel evolution of the primitive man into Homo sapiens, with his developed material and spiritual culture, was taking place there.

Below we will provide some archaeological, anthropological and genetic evidence to prove this thesis, connected with the evolution of the primitive population of Eurasia.

Homo orientalis

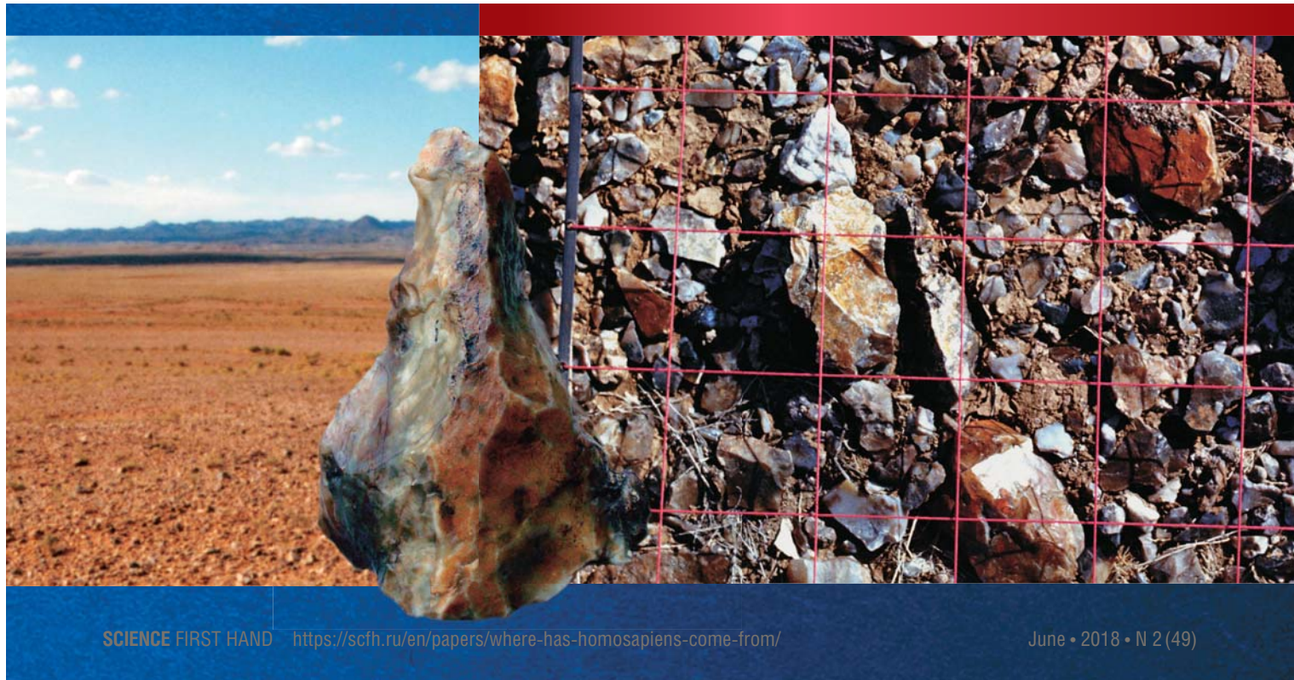
Judging by the numerous archaeological findings, approximately 1.5 Ma ago stone industry in East and Southeast Asia took a development path that was entirely different from the rest of Eurasia and Africa. Surprisingly, during more than a million years, tool-making technology in the Chinese-Malaysian zone did not undergo any marked change. Furthermore, as it was mentioned above, in the period of 80,000—30,000 years ago, when anatomically modern humans should have appeared here, no radical innovations took place: neither new stone working technologies nor new types of tools emerged.

As for the anthropological evidence, most of the known skeleton remains of *Homo erectus* were found in China and Indonesia. Despite some differences, they make up quite a homogenous group. Of special interest is the volume of the brain of Homo erectus (1152—1123 cm^3), found in the Yungxian District, China. Evidence of the advanced morphology and culture of these ancient people, who lived about a million years ago, is the stone tools discovered next to them.

The next link in the evolution of the Asian Homo erectus was found in Zhoukoudian caves, Northern China. This hominin similar to the Java pithecanthropus was classified in the *Homo* genus as a subspecies, *Homo erectus pekinensis*. Some anthropologists argue that all these remains of the earlier and more recent types of primitive people form a continuous evolutionary line extending almost up to *Homo sapiens*.

Thus, it can be taken for granted that over a span of more than a million years in East and Southeast Asia the Asian type of Homo erectus evolutionally developed independently from the rest of the world. This, however, does not rule out the possibility of migrations of small populations from the adjoining regions and, consequently, of genetic exchange. At the same time, the process of divergence that took place in these primitive humans themselves could have led to pronounced differences in morphology. An example is paleoanthropological discoveries from Java Island, which differ from the analogous

For 300,000 years, the unique Flint Valley in the desolate Gobi Desert served as a workshop for ancient stone craftsmen. There, at the outcrop of large siliceous breccias, there is a true "store field" of stone tools, over 20 square meters in area, where tens and hundreds of millions of tools are found – up to 600 per square meter!



Chinese findings of the same time: though Java hominin has preserved the primary features of Homo erectus, some characteristics of his were similar to these of Homo sapiens.

As a result, in the beginning of the Upper Pleistocene in East and Southeast Asia, on the basis of the local type of Homo erectus, a hominin anatomically close to a modern human formed. Supporting this view are the new datings of the Chinese paleoanthropological findings having the features of "sapiens," according to which 100,000 years ago this region could have been inhabited by anatomically modern humans.

Neanderthals come back

The first representative of archaic people that became known to science is the Neanderthal, *Homo neanderthalensis*. The Neanderthals mostly lived in Europe but traces of their presence have also been discovered in Near East, West and Central Asia and in the south of Siberia. These short stumpy people, physically strong and well adapted to the severe conditions of the northern latitudes, in terms of the brain volume (1400 cm^3) were on a par with modern humans.

In a century and a half that have passed since the first Neanderthals' remains were discovered, hundreds of their sites, settlements and burial grounds have been studied. It has turned out that these archaic people not only made quite advanced tools but exhibited some aspects of behavior typical of *Homo sapiens*. For instance, the well-known archaeologist A. P. Okladnikov in 1949, in Teshik-Tash Cave (Uzbekistan) discovered the tomb of a Neanderthal with the traces of what was presumably a ritual burial.

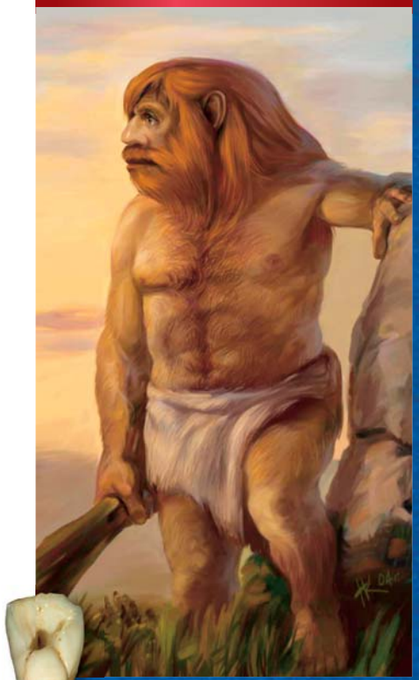
Prior to the beginning of the 21st century, many anthropologists classified the Neanderthals as an ancestral form of modern humans; however, after mitochondrial DNA from their remains was examined, they were treated as a dead end. The Neanderthals were considered to have been forced out and replaced by modern humans of African descent. Further anthropological and genetic studies have shown, however, that the relations between the *Neanderthals* and *Homo sapiens* were not as simple as that. According to the latest evidence, up to 4% of the modern humans' (not Africans') genome was borrowed from *Homo neanderthalensis*. Currently, there is no doubt that on the border of the areas populated by these humans not only cultural diffusion but also hybridization and assimilation took place.

Today, the Neanderthals are classified as a sister group of modern humans, and their status of "man's ancestors" has been restored.

In the rest of Eurasia, the development of the Upper Paleolithic followed a different path. Let us trace this development through the example of Altai region, which has produced some astonishing results obtained with the help of the paleogenetic examination of the anthropological findings from Denisova and Okladnikov caves.

One more member for the club

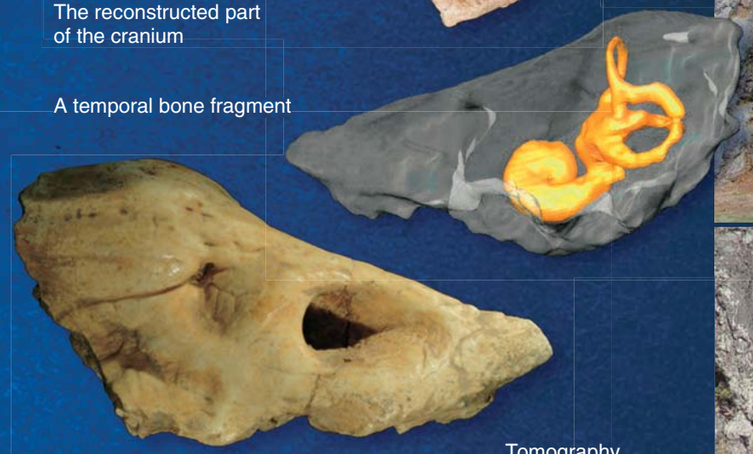
As mentioned earlier, man first came to Altai not later than 800,000 years ago, during the first migration wave from Africa. The uppermost occupation layer of the Paleolithic site of Karama in the Anui River Valley (the oldest site in the Asian part of Russia) formed about 600,000 years ago, after which the development of Paleolithic culture in this area took a long break. About

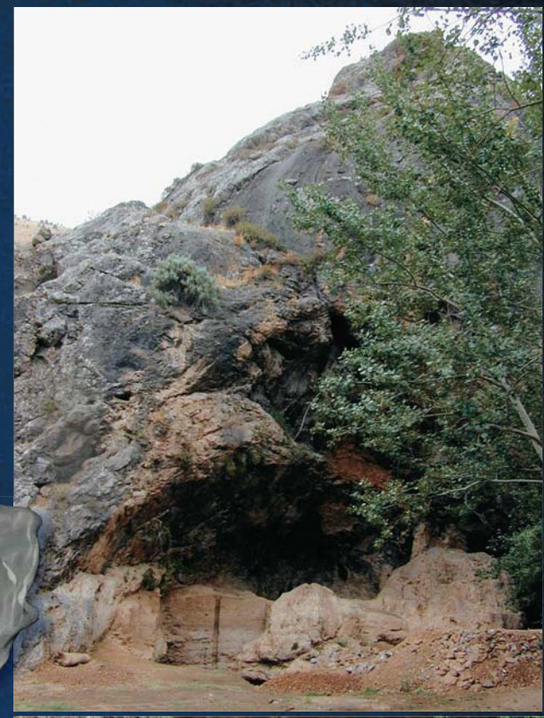


The results of the study of the cranium and teeth from the Obi-Rakhmat Grotto have proved to be sensational: the Obi-Rakhmat hominin has revealed mixed Neanderthal and modern human features, and many of its morphological characteristics have no paleoanthropological analogs

The reconstructed part of the cranium

A temporal bone fragment





Tomography reconstruction of the periodic bone labyrinthine

In Obi-Rakhmat Cave, Uzbekistan, stone tools dating back to the turning point – the Middle Paleolithic to the Upper Paleolithic transition – were discovered. Moreover, the fossil remains found here give a rare chance to restore the habitat of the humans who carried out technological and cultural revolution

280,000 years ago, carriers of more advanced stone working techniques came to Altai, and since then Paleolithic culture developed continuously.

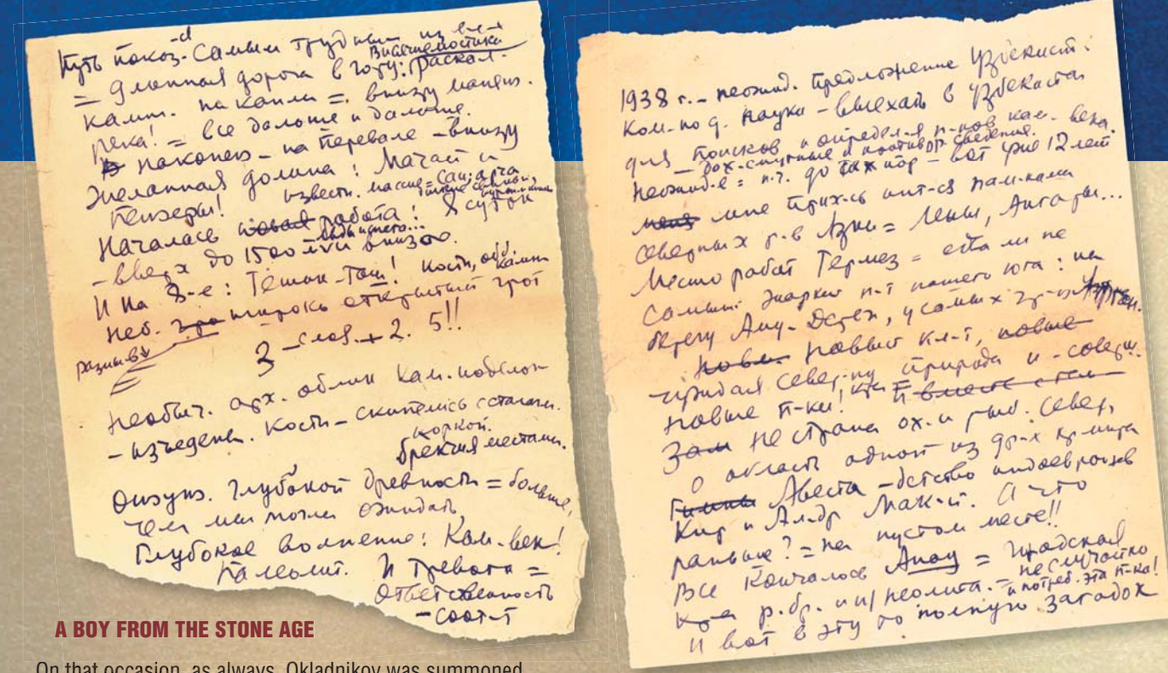
In the last twenty-five years, about 20 sites located in the caves and on the slopes of valleys in the Altai Mountains have been studied, and over 70 occupation layers of the Early, Middle and Upper Paleolithic have been examined. For example, in Denisova Cave alone 13 Paleolithic layers were distinguished. The oldest findings, dated the early period of Middle Paleolithic, were discovered in the layer aged from 282,000 to 170,000 years; Middle Paleolithic artifacts were found in the layer dating back to between 155,000 and 50,000 BP, and the Upper Paleolithic findings were dated to between 50,000 and 20,000 years ago. This long and "continuous" chronicle allows us to trace the changes that occurred in stone artifacts in many tens of thousands of years. It has turned out that it was a gradual process, a step-by-step evolution without any external "perturbations" – innovations.

Archaeological data testify that as early as 50,000–45,000 years ago Upper Paleolithic era began in Altai, and the sources of the Upper Paleolithic cultural traditions can be easily traced back to the final stage of Middle Paleolithic. Artifacts supporting this statement are miniature bone needles with drilled eyes, pendants, beads and other non-utilitarian things made of bone, ornamental stone and clamshell, as well as the truly remarkable finds: fragments of a bracelet and a stone ring with traces of grinding, polishing and drilling.

Regretfully, Altai Paleolithic localities cannot boast of many anthropological findings. The most impressive are the teeth and skeleton fragments from two caves, Okladnikov and Denisova, were studied in the Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany) by an international team of genetic scientists led by Professor Svante Pääbo.

Fragment of a field journal of A. P. Okladnikov *Uzbekistan, 1938*. Branch of the Archive of the Russian Academy of sciences, St Petersburg

The cranium of a Neanderthal, *Teshik-Tash, 1938*. Archive of the Institute of History of Material Culture, Russian Academy of Sciences, St Petersburg



A BOY FROM THE STONE AGE

On that occasion, as always, Okladnikov was summoned.

— A bone.

He came up, bent over it and began brushing it carefully. And then his hand trembled. This was not just one bone, there were many of them. Fragments of a man's skull. Heaven! Of a man! It was a find he had not dared to dream of.

Though could this person be buried here not long ago? It takes a few years for bones to decompose, and to expect that they will stay intact for dozens of millennia… Actually, it happens but very rarely. There is only a handful of such finds in the entire history of humankind.

But what if..?

— Verochka!

He called his wife below his breath.

She came up and bent over.

— This is a skull, she whispered. — Look, it's crushed.

The cranium was lying with the crown down. It must have been crushed by a falling clot of earth. The skull was small! A boy's or a girl's.

With a spade and a brush, Okladnikov began widening the dig. The spade hit against something hard. A bone. Another one, and one more…It was a small skeleton, the skeleton of a child. An animal must have found its way into the cave and picked the bones. They were scattered, some of them gnawed and bitten.

But when did this child live? In what years, centuries, millennia? If he was a young master of the cave when people who worked stone lived here … The thought was terrifying. If it was so, the child was Neanderthal. A man who lived tens of thousands or even a hundred thousand years ago. He must have a very pronounced brow ridge and no chin.

The easiest thing to do was to turn the cranium to have a better look but this would have disrupted the excavation plan. They had to complete the excavations around it leaving the child's bones untouched. The dig around them will deepen, and the bones will remain as though lying on a pedestal.

Okladnikov consulted Vera Dmitrievna, and she agreed with him....

... The child's bones were left untouched. They were even covered. The archaeologists dug around them, and the bones were on a ground pedestal, which became higher every day. It appeared to be growing from the underground.

The night before that memorable day Okladnikov had trouble falling asleep. He was lying on his back, hands behind his head, looking up at the black southern sky. Far above, the stars were swarming. They were so many that it seemed there was not enough room for all of them. That faraway world inspired awe and at the same time instilled serenity. You felt like thinking of life, eternity, the faraway past and the faraway future.

What could the ancient man be thinking about when he was looking up at the sky? It was the same as it is now. Maybe, sometimes he also had trouble falling asleep, was lying in the cave and looking up at the sky. Did he only have memories or did he have dreams as well? What was that man? The stones told a story but there were many things about which they remained quiet.

Life buries its traces deep underground. Overlaying them are new traces, which with time also go down. And so it happens century after century, millennium after millennium. Life puts layers of its past in the ground. Paging through them, an archaeologist can learn about the doings of the people who used to live here and to determine, virtually without mistake, the times when they lived.

Drawing the curtain above the past, they removed land layer by layer, as time had put them."

From the book *Along the path of faraway millennia* by Ye. I. Derevyanko and A. B. Zakstelsky

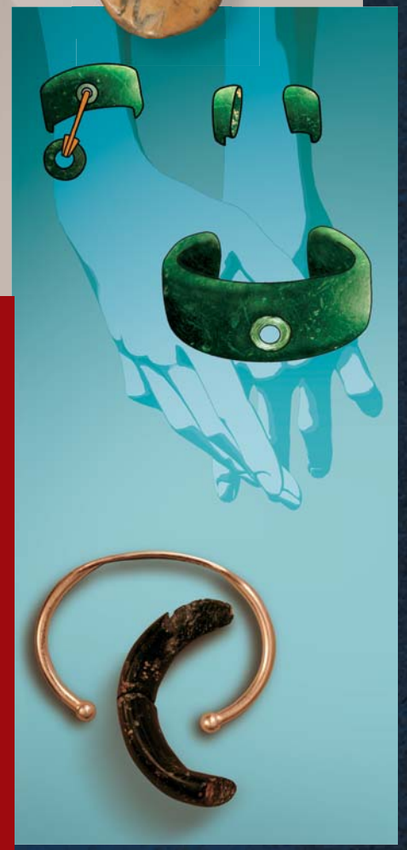
Paleogenetic studies confirmed that the remains discovered in Okladnikov Cave were Neanderthal whereas the results of the sequencing of mitochondrial and then nuclear DNA from the bone samples discovered in the occupation layer of the Upper Paleolithic early stage in Denisova Cave sprang a surprise on the researchers. The bone fragments proved to belong to a new fossil hominin, unknown to science, who was given the name of Homo sapiens altaiensis, or Denisovan, after the locality where he was discovered.

The genome of the Denisovans differs from the reference genome of a modern African by 11.7 %, and that of the Neanderthal from Vindija Cave, Croatia, by 12.2 %. This similarity testifies that the Neanderthals and Denisovans are sister groups with the same ancestor, who branched off the man's mainstream evolutionary trunk. These two groups separated approximately 640,000 years ago, taking the path of independent development. Another proof is that the Neanderthals share some genetic variants with modern Eurasians whereas some of the Denisovans' genetic material was borrowed by the Melanesians and indigenous inhabitants of Australia, who stand apart from other non-African human populations.

Judging by the archaeological data, 50,000—40,000 years ago, in the northwestern region of Altai two different groups of primitive people lived next to each other: the Denisovans and the easternmost population of the Neanderthals, who came there at about the same time, probably from the territory of modern Uzbekistan. The roots of the culture whose carriers were the Denisovans can be traced back to the earliest sequences of Denisova Cave, as it was mentioned earlier. Interestingly, according to the panoply of archaeological findings reflecting the development of the Upper Paleolithic culture, the Denisovans were not

A most rare find of Denisova Cave – a tooth of one of the first Asian *Homo sapiens*

These unique artifacts of the Upper Paleolithic culture (a necklace, needles and a bracelet) testify that in Altai the Upper Paleolithic began earlier than in Europe



Novosibirsk archaeologists have been excavating Pleistocene sediments in Denisova Cave, the Altai Mountains, where man first appeared about 300,000 years ago

Denisova Cave is a dependable repository of the ancient history of Altai
Photograph by M. Shunkov

only on a par with the anatomically modern humans inhabiting at that time other territories but in some respects were superior to them.

To sum up, during the Late Pleistocene there were at least two other forms of hominines in Eurasia: Neanderthal in the western part of the continent and Denisovan in the eastern. Taking into consideration the gene drift from the Neanderthals to Eurasians and from the Denisovans to the Melanesians, we can take it that both these groups have contributed to the formation of anatomically modern humans.

The third upper molar, a wisdom tooth of a Denisovan, discovered in the lithologic layer 11 within the sediments dating back to 50,000-40,000 BP

In the eastern gallery of the cave, a small fragment of the terminal phalanx of the minimus of a child, presumably, a girl 5—8 years old

Taking into account all the available archaeological, anthropological, and genetic materials from the oldest localities of Africa and Eurasia, it can be presumed that the globe had several areas where Homo erectus populations and stone working technologies developed independently. Respectively, each of these areas generated its own cultural traditions and its own models for the transition from the Middle Paleolithic to the Upper Paleolithic.

Thus, the basis of the evolutionary sequence crowned with the anatomically modern humans is the ancestral form of Homo erectus sensu lato*. Probably, in the Late Pleistocene it ultimately developed into the humans of the anatomically and genetically modern species Homo sapiens including four forms that can be referred to as Homo sapiens africaniensis (East and South Africa), Homo sapiens neanderthalensis (Europe), Homo sapiens orientalensis (Southeast and East Asia) and Homo sapiens altaiensis (North and Central Asia). In all likelihood, the idea to unite all these primitive people into a single species, Homo sapiens, can give rise to doubt and objections but it has to be remembered that it is based on a large body of analytical information, only a small part of which was given in this paper.

Evidently, not all of these subspecies have contributed equally to the formation of anatomically modern humans: Homo sapiens africaniensis featured the greatest genetic

* *Homo erectus sensu lato – Homo erectus in a general sense*

In archaeology everything matters down to the last detail. Chief of the Laboratory of Mammals, Prof. A.K. Agadzhanyan (the Paleontological Institute, Russian Academy of Sciences, Moscow) and his assistant are examining the cave ground on the bank of the Anui River
Photograph by S. Zelenskiy

diversity, and it was he who laid the foundation for the modern human. However, the most recent data of paleogenetc research dealing with the presence of Neanderthal and Denisovan genes in the gene pool of modern mankind have shown that the other groups of ancient people did not stand back either.

Currently, archaeologists, anthropologists, experts in genetics and other specialists interested in human origin have accumulated an enormous number of new data basing on which new hypotheses, sometimes diametrically opposite, can be formulated. It is high time to discuss them in detail under the essential condition that man's origin is a multidisciplinary problem and new ideas should be based on a complex study of the results obtained by the specialists of a wide variety of sciences. Only this way will ultimately give us the answer to one of the most controversial questions that has stirred people for centuries – the development of intelligence. According to Thomas Huxley quoted above, "each of our firmest convictions can be overthrown or, at least, revised by further successes in knowledge."

Drawing by N. Kovalev

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A. I. KRIVOSHAPKIN

ORIGIN OF MAN: A Fight for Neanderthal LEGACY

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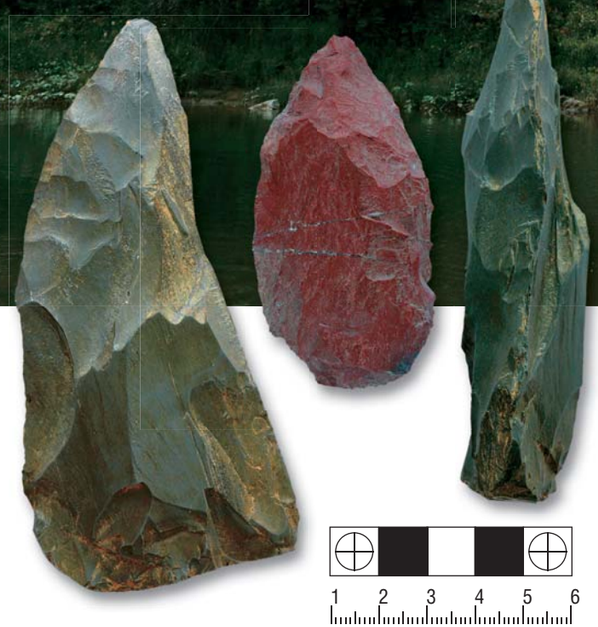
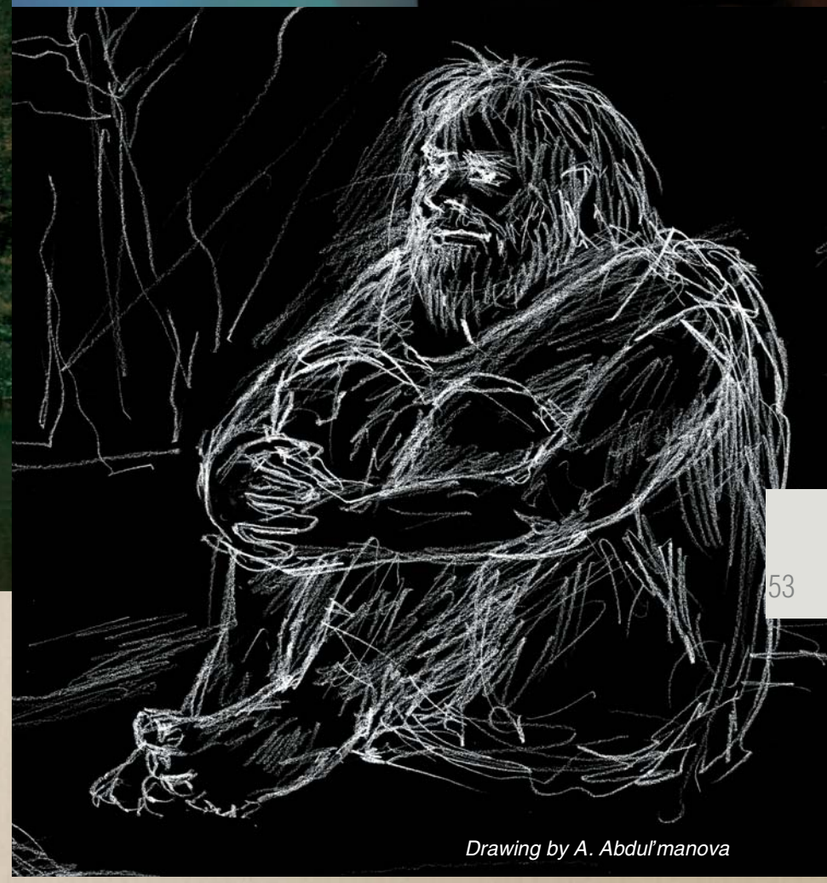


Chagyrskaya Cave in the Krasnoshchekovo district (Altai krai), where researchers have found over the last decade in deposits dating back 60,000–50,000 years numerous stone (*left*) and bone tools as well as bone remains of Neanderthals. *Photo by S. Zelensky and A. Fedorchenko*



Drawing by A. Abdul'manova

Many people must have wondered, at least once in their life: What are modern humans? How did they originate? How do they differ from, say, Neanderthals or Pithecanthropi? A bombshell discovery that revolutionized our understanding of the origin of man and overturned the theory of anthropogenesis occurred when archaeologists found fossil anthropological remains in the Altai Mountains, leading paleogeneticists to open a new chapter in the history of modern humans

Key words: human evolution, anatomically modern humans, multi-regional theory of human origin, "Out-of-Africa" theory, ancient DNA

Until recently, both reputable scientific volumes and school textbooks considered human evolution as a single progressive pathway towards the appearance of the jewel in the crown – the modern man. At the very roots of this genealogical tree, they placed Australopithecines, who were still not humans but apelike fellows who strode confidently towards becoming *Homo sapiens*.

It was accepted that the first "real" human was the African Man of Skill (*Homo habilis*), a fairly handsome guy by our standards, whose remains were first discovered by the Leakey couple in the Tanzanian gorge of Olduvai in 1960. It is believed that this primitive man was the first to apply tools to change the world, unlike its predecessors, who sought to adapt to the world.

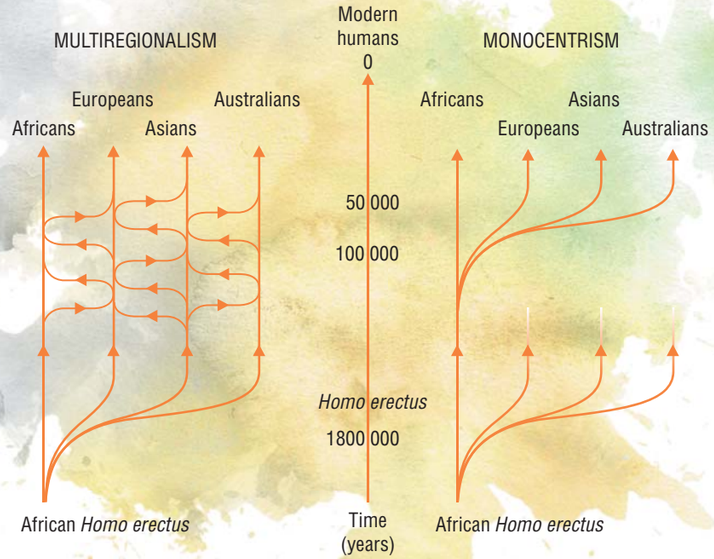
Then, as this harmonious theory says, the Man of Skill evolved gradually, for various reasons, becoming smarter and handsomer, until it transformed into a Pithecanthropus. Although still an "ape–man," as follows from the translation of its name, the Pithecanthropus could stand firmly on its feet, literally and figuratively, and was called, therefore, *Homo erectus*, or the Erect Man. This man hunted for food and was developing in every direction.

It was the erectus who started the victorious march through the lands of the Old World. In Europe, it evolved into the Neanderthal Man (*Homo neanderthalensis*), popularly known as a cute, though clumsy, guy. Neanderthals did so well in Europe that over time, they developed into the man of the modern type. This landmark event occurred, as believed, about 40,000 years ago. The new player in the evolutionary arena gradually ousted all the others and successfully spread throughout the free lands, reaching the American continent.

They say that tribes still exist that do not know how to make and use fire. What development stage can they reach? Could man survive without fire?

It would not have been possible to survive without fire in Siberia but somewhere in Africa—why not? Until reaching a certain stage in its evolution, man could have existed without fire. We have evidence that humans who were at higher stages of development (Denisovans and Neanderthals) interbred with representatives of a very archaic mankind, e. g., Homo erectus, who could have lived without using fire. And all this happened in the not-too-distant historical past. Probably, by that time these primitive people could have survived in some isolated habitats, on islands, and then either merge into the body of mankind or disappear. But I personally do not think that today there are tribes that do not use fire

Drawing by A. Abdul'manova



The theory of the origin and evolution of man has also been evolving. The simple linear model gave way to two tree-like ones. The multiregional model (*left*) assumes the independent formation of the modern man in different regions across the planet, and the monocentric model (*right*), which is based on the study of ancient DNA, insists on its African origin given limited interbreeding with archaic humans. *Adapted from: (Gibbons, 2011)*

This human development theory existed until the end of the twentieth century; all modern researchers of ancient past grew up on it. But then evidence began to appear that did not fit into this coherent picture. For example, archaeologists found in the Middle East fossilized remains belonging to a modern-type man yet dating back 90,000 years. Where did they come from?

These suspicious primitive people, whose remains began to pop up not only in the Middle East but also in other parts of the world, were called advanced Neanderthals and looked upon as immediate predecessors of modern humans. However, the most critical discovery was made with the advancement of paleogenetics, which brought fossil DNA into the focus of research. It turned out that our human subspecies was formed not 40,000 years ago: this process has been going on for the past 200,000 years and not as simply as one used to think.

From simple to complex

When the straightforward approach to human evolution gave way to a sophisticated, tree-like one, the latter, in turn, branched into several points of view. One of them, less radical, places the origin of man in Africa, but believes that it left this continent very early to settle in different lands, where it subsequently developed independently of others. Those who share this *multiregional hypothesis* are usually among the most venerable scholars, who rely on the data obtained within traditional disciplines such as paleoanthropology or archaeology.

Recently, another, *monocentric theory* has become widespread, according to which all people are out of Africa. The black continent not only is the homeland of the oldest population on our planet, all the subsequent waves of migration originated here, including the modern man, who also appeared in Africa and only afterwards spread across the expanses of Eurasia, mixing with the local population who lived there at that time.

Today, the multiregional point of view is supported by archaeological evidence, which shows a gradual, progressive development of the material culture of ancient man almost everywhere in the world. The monocentric theory, however, is supported by the data of natural sciences, primarily paleogenetics. The truth, as always, lies somewhere in between. In any case, all scientists agree that mankind originated in Africa. The African cradle hypothesis is confirmed by both anthropological and archaeological data, including the most ancient stone tools, dating back more than 3 million years.

In modern understanding, about 2 million years ago, man left for the first time its African homeland and reached the expanses of Eurasia. It was indeed the first representative of the genus *Homo*, the Man of Skill, who made this step; although this man is often named differently, in local way, in different regions. For example, the remains of nine individuals belonging to one of its species, which were found in Dmanisi, Georgia, were called the "Georgian Man." However, there are arguments to support this view: many

If we accept our African origin, then all the main genetic waves must have formed in Africa. What caused the migrations?

Africa is also called a "kettle," as it provided good conditions for reproduction. And then what? There are such concepts as an ecological niche and a demographic explosion. When a human population lives in one place for a long time, it exhausts the resources of that place, especially if this group does not produce anything, only consumes. Of course, primitive people did not intend to conquer Eurasia, of which they had no idea. They simply went to where they were better off, as is evident from their sites, which mark the path of their migration. All of them are located in places with familiar ecological conditions, relief, etc. The same phenomenon was discovered at the Angara River in the study of local Neolithic monuments. If you dig a river bank there, you will encounter again and again, for kilometers, the sites of early hunters who moved along the river as they exhausted the local resources

scholars believe that the Dmanisi hominins had already made the step from the Man of Skill to a more advanced (in morphological terms) subspecies of *Homo ergaster*.

Gradually, man moved further and further across the Eurasian continent up to its northern borders. Of course, we are not talking about directed migration or about large crowds; humans were moving in small groups from one habitat to another, e. g., after the herds of animals they hunted.

It should be emphasized here that the descendants of the first wave of ancient migration, associated with *Homo erectus*, reached the Altai Mountains. The earliest evidence of human presence in North Asia was discovered near Denisova Cave: the well-dated primeval Karama site, whose age is no less than 800,000 years! In the 1980s, researchers attempted to use the finds from Yakutia to support the hypothesis of earlier settlement of North Asia, but the Yakutian artifacts, unlike the Altaic ones, still remain controversial. In any case, we are now certain that Siberia participated in the primary settlement of the human population.

The next mass migration of humans from Africa took place much later (about 400,000—500,000 years ago) and was associated with developed forms of the Erect Man, better known as the Pithecanthropus. This time, humans reached even more distant regions of Eurasia, including Siberia. It is with this wave that we now associate the boom in the development of stone tool making and animal hunting. These primitive people, who had clothes and dwellings, were well adapted to survive in environments much more severe than in Africa.

Clearly, the division of human "exoduses" into the first and second waves is a formality. In this way, we merely seek to highlight the most significant events.

Discovery of the Third Man

As mentioned above, the first evidence of human settlements in the Altai Mountains dates back roughly 800,000 years. Then comes a large gap: apparently, in the period 600,000—300,000 years ago, no humans lived in the Altai and, generally, in West Siberia, most likely due to the not particularly benign climate. The human population that lived at that time in these latitudes must have been small and could have disappeared through the action of biological laws.

The next known "outpost" of man in the Altai is Denisova Cave. The lowest ancient layers of deposits at this site date back about 300,000 years, i. e., are attributed to the second global wave of human migration. Since that time man has been settling, actively and successfully, across the entire territory of the Altai.

It was Denisova Cave that hosted the truly fantastic discovery of a new subspecies of man, which was called the Denisovan, or the Altai Man (*Homo altaiensis*). The cave is being studied thoroughly and systematically: over the years, researchers have found in the cave deposits numerous fossil bones of animals yet very few, isolated anthropological remains. Among these, there was a small bone, the distal phalanx of a child's little finger, found in 2008 in the eastern gallery of the cave in a more than 40,000 years old layer; i. e., the bone belongs to the time of the supposed transition from the Neanderthal to the Modern Man.

In 2009, this find was sent for a detailed analysis to the paleogenetics laboratory of Prof. Dr. Svante Pääbo from the Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany). Siberian archaeologists had cooperated previously with Pääbo's team: the German researchers analyzed the mitochondrial DNA from the remains found in Okladnikova Cave in the Altai Mountains, South Siberia and proved that they belonged to a Neanderthal man.

As for the finger phalanx from Denisova Cave, archaeologists had been certain that the bone belonged to a man of the modern physical type, rather than to a Neanderthal. They even put it on the label on the plastic bag in which they sent the bone to the paleogeneticists. Curiously, the 2017 exhibition dedicated to the Third Man and Denisova Cave demonstrated, in addition to the phalanx itself, the above mentioned historical plastic bag with the erroneous inscription on the label.

The first surprising result obtained by studying the DNA from the phalanx was its excellent preservation. Denisova Cave and the entire region is a well of information for paleogenetic studies, because of the unique climate in the Altai Mountains and, specifically, in the cave. The special temperature regime allows very good preservation of organic material in the local caves. Archaeologists even joke that a real Denisovan mummy may lie there somewhere.

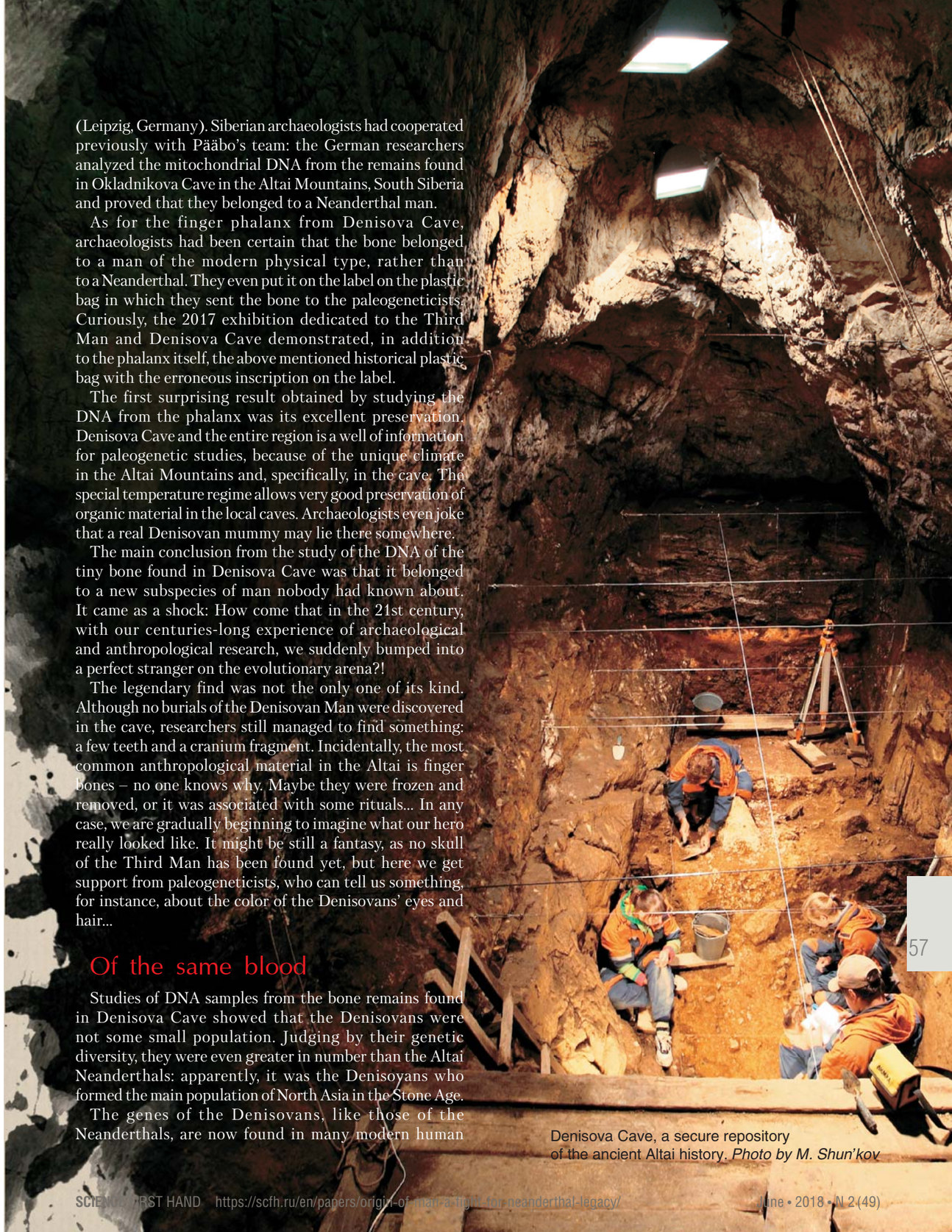
The main conclusion from the study of the DNA of the tiny bone found in Denisova Cave was that it belonged to a new subspecies of man nobody had known about. It came as a shock: How come that in the 21st century, with our centuries-long experience of archaeological and anthropological research, we suddenly bumped into a perfect stranger on the evolutionary arena?!

The legendary find was not the only one of its kind. Although no burials of the Denisovan Man were discovered in the cave, researchers still managed to find something: a few teeth and a cranium fragment. Incidentally, the most common anthropological material in the Altai is finger bones – no one knows why. Maybe they were frozen and removed, or it was associated with some rituals... In any case, we are gradually beginning to imagine what our hero really looked like. It might be still a fantasy, as no skull of the Third Man has been found yet, but here we get support from paleogeneticists, who can tell us something, for instance, about the color of the Denisovans' eyes and hair...

Of the same blood

Studies of DNA samples from the bone remains found in Denisova Cave showed that the Denisovans were not some small population. Judging by their genetic diversity, they were even greater in number than the Altai Neanderthals: apparently, it was the Denisovans who formed the main population of North Asia in the Stone Age.

The genes of the Denisovans, like those of the Neanderthals, are now found in many modern human



Denisova Cave, a secure repository of the ancient Altai history. *Photo by M. Shun'kov*

populations. Interestingly, the most abundant genetic heritage of the Altai Man was found in Melanesia: the population of Papua New Guinea and the aborigines of Australia inherited up to % of their DNA from the Denisovans. Why it happened remains a mystery since the vast expanses of China lie between the Altai and Oceania and the attempts to extract DNA from the bone remains discovered there have failed so far because of its poor preservation. Therefore, it is not yet possible to answer the question of how Denisovan genes got so far from the Altai Mountains.

However, the main outcome from studying the DNA of the Denisovans is the understanding that all primitive people that existed throughout the history of mankind, including Pithecanthropi and Neanderthals, were subspecies of *Homo sapiens* rather than independent species. This is a very important point since different species cannot produce fertile offspring. Judging by the presence of the Denisovan and Neanderthal legacy in our genome, these representatives of primitive mankind were able to interbreed, producing fertile offspring.

Based on reconstructions of ancient people's habitat, the Altai climate 50,000–70,000 years ago was arid and relatively cold. The main occupation of people was hunting for steppe animals, mostly bisons. *Top*: bison's jaw from Chagyrskaya Cave. *Photo by S. Shnaider*

Do the finds from Denisova Cave give any clue about how Denisovans and Neanderthals got along? Did they feud with each other, or was it peaceful coexistence?

Judging by the tools that Denisovans made, we can argue that there is likely no evidence of the presence of the Neanderthal material culture in Denisova Cave. But then the question arises: Where did their bones come from? Perhaps, Denisovans ate Neanderthals (which we cannot rule out) or entered into marital relations with them. As for conflict situations, we used to have a beautiful theory that said that modern-type humans, who had had a developed culture, came to Europe, which was inhabited by Neanderthals, and ousted the local population. The latest Neanderthals were discovered on the periphery of Europe, i.e., in the Mediterranean, in Portugal, where they finally died out. It is now difficult to say whether the alien migrants ousted the Neanderthals through armed conflict or war. However, the hunting tools that modern-type humans possessed made it possible for them to kill other humans

Drawing by A. Abdul'manova

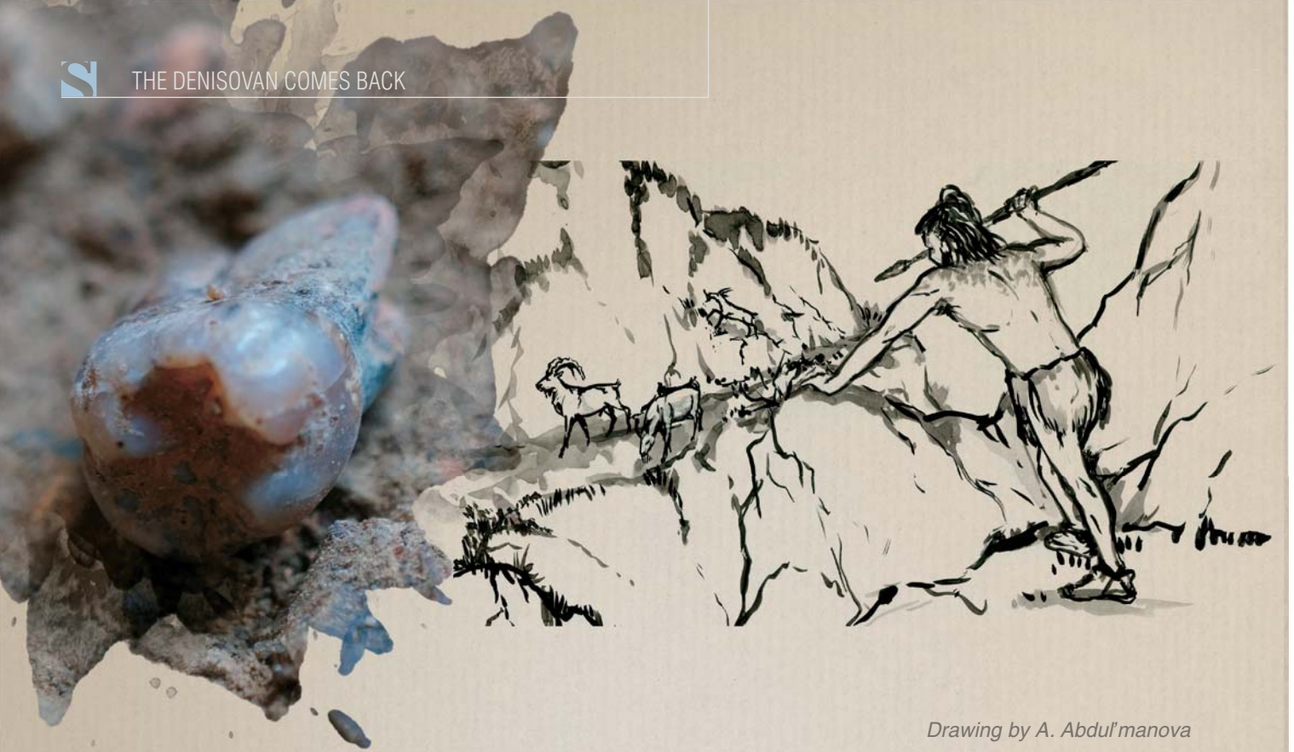
Bone retoucher was the first tool that ancient humans used to make other implements. The retoucher from Chagyrskaya Cave was made of a bison bone. *Photo by A. Fedorchenko*

This argument is further supported by other amazing finds from Denisova Cave. For example, in the same layer that contained the phalanx of a Denisovan girl, researchers found a fossil phalanx of a toe, which was preliminarily classified as remains of a Denisovan. However, paleogenetic analysis showed that it belonged to a Neanderthal! Moreover, since this DNA was so well preserved, researchers were able, for the first time in the world, to restore the full Neanderthal genome.

The joint efforts of archaeologists, anthropologists and paleogeneists presented us with evidence of several episodes of interbreeding between Denisovans and Neanderthals and between Neanderthals and anatomically modern humans. In addition, the study of the paleogenetic material from Denisova Cave suggests subsequent (on the scale of the Stone Age, of course) interbreeding with an even more archaic population. Presumably, those were the descendants of *Homo erectus* who survived in the nooks of Eurasia.

In addition to this fascinating, enigmatic story with interbreeding, researchers are now vigorously investigating the history of how Neanderthals appeared on the expanses of Siberia. Recent discoveries in Chagyrskaya Cave, the data from repeated analyses of anthropological and archaeological materials from Okladnikova Cave, and the results obtained by analyzing the Neanderthal DNA from Denisova Cave show that different Neanderthals used to live in the Altai and they came there more than once from different parts of the Old World.

What attracted these ancient people to Siberia? How did they get on with the human populations that had come here earlier? Why have no remains of early humans of the modern type been found in the Altai? Is it possible that the ancient objects of Paleolithic art (pendants, beads, etc.) found in Denisova Cave were made by Denisovans? If we can prove the latter, this sensational finding may have a greater resonance than the discovery of the Denisovan Man itself.



Drawing by A. Abdul'manova

Tooth of a Neanderthal man in a cultural layer. Chagyrskaya Cave. *Photo by S. Shnaider*

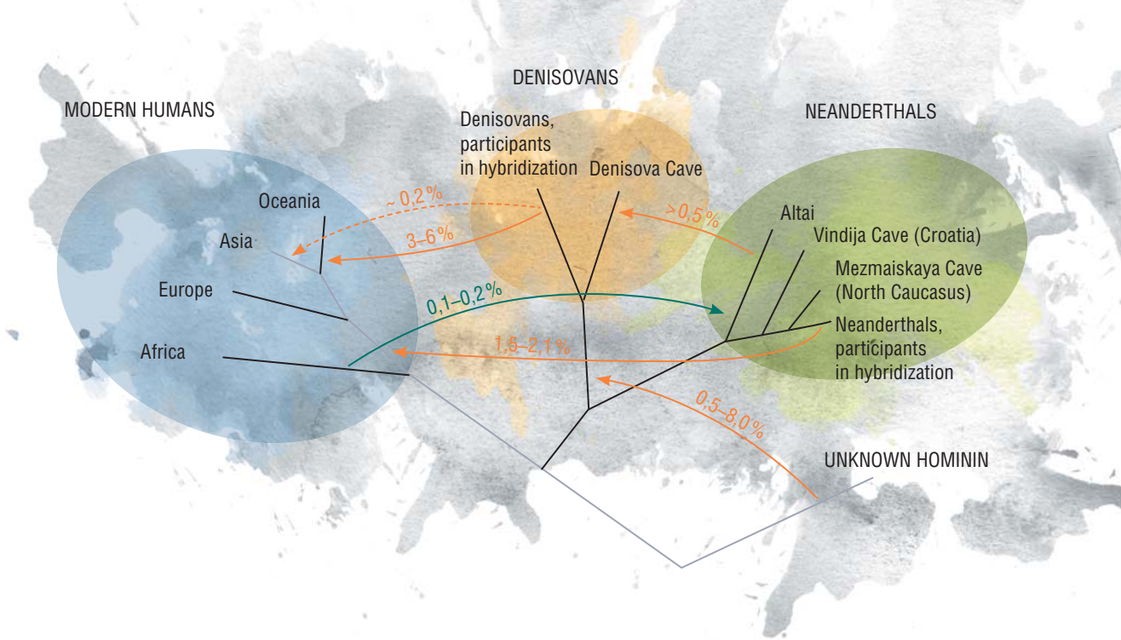
When did anatomically modern humans first appear in Siberia?

Today, we understand the culture of the Siberian Neanderthals and Denisovans relatively well but have little information on modern humans in the Altai. The earliest such find in North Asia was the tibia from Ust'-Ishim (Omsk oblast), which dates back 45,000 years. An interesting fact: the DNA analysis of this find revealed a relatively recent cross-breeding with Neanderthals, but showed no presence of Denisovan genes. Perhaps, the cross-breeding with Neanderthals occurred early in the process of resettlement of the original human population, most likely, in the Middle East. However, this is a random find, unaccompanied by any artifacts; therefore, the time when modern humans first appeared in Siberia, as well as their interactions with Denisovans and Neanderthals, remains a mystery

The more new data we acquire, the better our understanding of our past and, on the other hand, the more mysteries arise...

The latest anthropological findings, primarily, the discovery of the Denisovan Man in the Altai, suggest that the evolution of the modern man occurred neither in a linear nor even a tree-like pattern. Our family tree looks more like a dense bush whose branches intertwine over and over again.

Today, the evolution of man is commonly represented, in a visually compelling way, as braided streams – as a river with the main channel, from which other streams branch. Some of them may get lost, or break through unexpectedly and merge into another stream. Today, we know a lot about some human streams, but paleogenetic data tell us that there may have been other streams, as yet unnamed, which may have also contributed to the ocean of modern mankind.



This model presents possible gene flows in the human population of the Late Pleistocene. The scheme shows the direction and estimated value of the possible events. The dashed line indicates the infusion of Denisovans into the modern genome, which could have occurred both once and repeatedly. *Adapted from: (Prüfer et al., 2014)*

Probably, if we now carried out excavations in those places where the earliest archaeological finds were discovered, they might give much more information. For example, if Dubois had found that phalanx of a Denisovan child, it would have been useless. Perhaps, it makes sense to leave something for the future, until better times?

Chinese wisdom says: "If you wait by the river long enough, the bodies of your enemies will float by." Perhaps, great discoveries can be made through waiting. It's true: we need to move forward, but we need to leave something too. For example, there once was a technique for studying small caves, when they were literally excavated to the full. The advantage of this method was that the resulting finds could serve to make interpretations of where and how people ate, slept, made fires, etc. In this way, we can obtain a good comprehensive picture of a large site. But what if we dig everything out today, and in a decade, we invent a miracle device capable of recreating a holographic image of what was once happening in the cave... It is important to maintain a balance, as is written in the field archeology textbook, and leave a spot for future control excavations. Therefore, it is necessary to excavate, but it is also necessary to leave something

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Ио: Nauka iz Pervykh Ruk, № 1(77)

THE MAN'S FAMILY TREE has branched out

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Key words: paleogenetics, mitochondrial DNA, nuclear DNA, hominid, Neanderthal, Denisovan

The discovery of a previously unknown ancient hominid, based on paleogenetic data, was included by "Science" magazine into the list of the most important advances of the last two years. By analogy with the Neanderthal man, this new species was named the Denisovan after the site where the anthropological fossils were found, namely, the Denisova Cave in the northeast of Gornyi Altai. The quantum leap that took place in these studies in 2011 resulted from a successful sequencing of the Denisovan nuclear DNA and from an accurate assessing of the contributions of two kindred hominid groups – Neanderthals and Denisovans – to the gene pool of contemporary humankind

Recently, the evolution of mankind from the early hominids to Homo sapiens was believed to be a relatively straight "line". In light of this concept, the Neanderthal was recognized as the immediate ancestor of man of the modern physical type. However, extensive development of paleogenetic studies at the end of the last century, based on the sequencing of mitochondrial DNA * from fossil bones, suggested that Neanderthals were a dead end in human evolution. This implied that being a separate and reproductively isolated species, an "alternative mankind," Neanderthals could not have played any prominent part in the history of Homo sapiens.

The situation changed dramatically in the year 2010, when a new player – the Denisovan man, a representative of the new group of ancient hominids discovered in Gornyi Altai – appeared on the evolutionary stage. This discovery stimulated active paleontological efforts which have resulted in truly revolutionary discoveries in the field of ancient history of mankind. Since the new data were mainly obtained from sequencing the nuclear rather than mitochondrial DNA, they have considerably increased both the volume and quality of the paleogenetic information obtained.

First, it has been proved that up to 4 % of the contemporary human genome "belongs" to the Neanderthals (Green *et al.*, 2010), thereby suggesting possible crosses between these two species at a certain stage of evolution. As for the Denisovans, they "possess" 4 to 6 % of the genome of contemporary southern hemisphere dwellers, namely, the aborigines of Australia and the Melanesian islands (Reich *et al.*, 2010).

Note here that the Sea Level changed considerably during various periods of the Pleistocene and that every now and then the entire region was a firm land – the protocontinents Sunda and Sahul. Correspondingly, humans could move southward from Asia and settle in the areas up to Australia, which is confirmed by modern genetic data.

In light of new paleogenetic data, both the Neanderthals and Denisovans got the right to be regarded as ancestors of modern mankind. But when did the so-called gene drift take place? As for the Denisovans, it is unlikely that the carriers of this genome came to the southern coast of Asia directly from Altai, for their "fingerprints" have not been found in the genotype of the population inhabiting transitional East and Southeast Asian areas. The genetic material of three species was likely to mix somewhere in West Asia approximately 100—80 TYA during another "advent" of *Homo sapiens* from their historical African motherland. Only then did *Homo sapiens*, carrying the genes of Denisovans and Neanderthals, settle in southeastern Eurasia and Australia.

These discoveries suggest a new model of anthropogenesis as opposed to the doctrine of monocentrism, which states that the only place where man of a modern physical type originated from East Africa, from where the mankind then spread over Eurasia.

The doctrine of polycentrism, i. e., the idea of several places of origin where man of a modern physical type had formed has for several years been successfully developed by Academician A. P. Derevyanko (2011) and his scientific school at the Institute of Archaeology and Ethnography (Novosibirsk, Russia). The developing of the theory was enhanced by the results of a long-term unique research of Novosibirsk archaeologists in Altai, the discovery of the Denisovan man being its climax. In that area, the researchers succeeded in recording the picture of a gradual and continuous development of human culture over a tremendous time period that covered at least about 300,000 years. The objects found reflect the level of Denisovans' material and intellectual culture, suggesting that they were not inferior to other people of the modern physical type who lived at the same time in other regions.

It should be noted that the Denisovan bone fossils are still few, represented only by several teeth and a phalangeal bone. The anthropological fossils suggest that this group, from a morphological standpoint, was more archaic than the Neanderthals and was closer to *Homo erectus* on the evolutionary stairway. As for the paleogenetic data obtained

For many years Novosibirsk archaeologists have been involved in excavations of the Pleistocene deposits in the Denisova Cave (Gornyi Altai, Russia), the most ancient Paleolithic site in Siberia, where man appeared for the first time about 300 TYA. *Right*, the third upper molar, a "wisdom tooth" of the Denisovan man, found in lithological layer 11, which is 50,000—40,000 years old

* Mitochondria, a cell's organelles, which are its representing cell's energy "plants", have their own DNA, which is inherited exclusively in the maternal lineage. The nucleotide sequence of this DNA is much shorter and, correspondingly, carries incomparably less information than the DNA residing in the cell nucleus

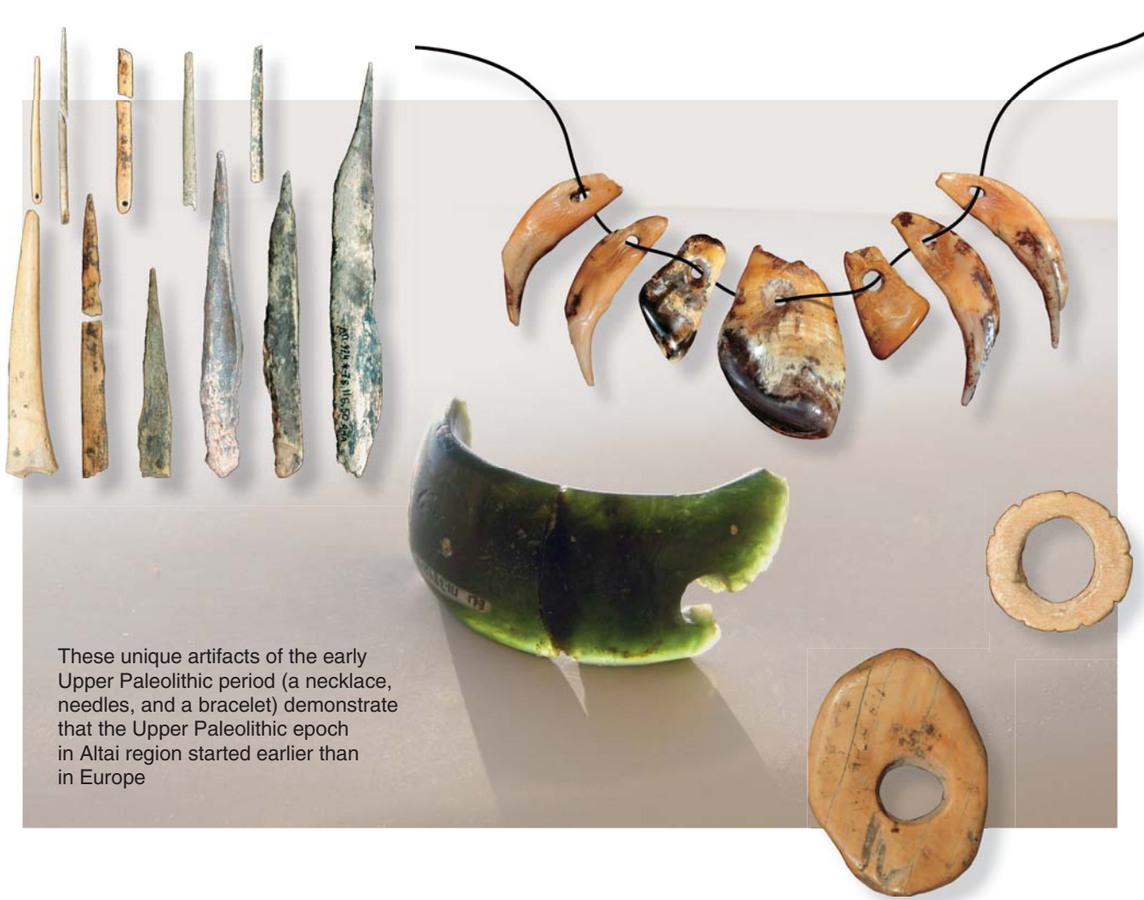
The Anui River valley, housing the Denisova Cave research station of the Institute of Archaeology and Ethnography, served for millennia as a refugium for many species of living beings, humans included, owing to a unique combination of favorable environmental conditions

from the three bone specimens from the Denisova Cave, they showed an unexpectedly broad genetic diversity, considerably larger as compared with that discovered in the Neanderthals, who lived on a vast territory from Western Europe to Southern Siberia. These data demonstrate that the Denisovans were a rather stable group with deep ancient roots.

The paleogenetic data resulted from studying the bone fossils of the Neanderthals from the Okladnikov and Chegyrskaya Caves, located near the Denisova Cave, as well as stone artifacts typical of this particular group and well known in the Near East and Western Europe were also of paramount importance. Taken together, these archaeological, anthropological, and paleogenetic data make it possible to state that two different groups of prehistoric people lived in northwestern Altai lowlands in the basins of the Anui and Charysh Rivers approximately 50—30 TYA. Moreover, the Neanderthals came there approximately 50 TYA, probably, from the territory of modern Uzbekistan, while the roots of the culture whose carriers were the Denisovans, as mentioned above, are traceable in more ancient horizons of the Denisova Cave.

Unfortunately, it is still impossible to determine when and how the evolutionary tree of the mankind, including the Neanderthals and Denisovans, branched off. Analysis of the nuclear DNA suggests only that these were sister groups, and that the branch of these hominids' common ancestor was the first to separate from the common tree, their divergence following.

Further paleogenetic research, acquiring an ever more integrated character, is sure to bring about many surprising discoveries. Currently, large international teams are



These unique artifacts of the early Upper Paleolithic period (a necklace, needles, and a bracelet) demonstrate that the Upper Paleolithic epoch in Altai region started earlier than in Europe

working in this field. One of the most efficient teams is supervised by Prof. S. Pääbo, head of the Department of Evolutionary Paleogenetics with the Max Planck Institute for Evolutionary Anthropology (Leipzig, Germany). It is this particular team, which unites dozens of scientists from large scientific institutions of Europe and America, that has sequenced the Neanderthal genome and performed a paleogenetic "reconstruction" of the Altai anthropological fossils.

Among the latest achievements in the field of anthropological paleogenetics are the data gathered by a team from the Stanford University School of Medicine about archaic alleles (variants) present in the modern human genome (Abi-Rached *et al.*, 2011). This research team hypothesized that our archaic ancestors had significantly influenced the formation of our immune system. In other words, the blending of the genetic material of the Neanderthal, Denisovan, and *Homo sapiens* made man of a modern physical type better "protected" against the impacts of adverse environmental factors. Although these results require further substantiation, they show that paleogenetic studies, unraveling the mystery of our origin, have not only a tremendous theoretical significance, but also potential applications in modern medicine.

The photos are by the courtesy of S. Zelenskii (Institute of Archaeology and Ethnography, Siberian Branch, Russian Academy of Sciences, Novosibirsk)

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ANCIENT DNA has revealed its secret

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Key words: ancient DNA, paleogenetics, paleogenomics

According to the experts of the "Science" magazine, a successful application of molecular genetic methods in archaeology and paleontology is the third in the list of research advances of the first decade of our century. The new methods for DNA decoding have provided information about the genome structure of extinct organisms that lived tens of thousands years ago, which has given rise to unprecedented progress in these traditional fields of knowledge

Paleogenetics, a modern research field at the interface of archaeology and molecular genetics, has been actively developing owing to an ever wider application of high-throughput DNA sequencing (decoding) methods.

Until recently, several unsolved problems interfered with the development of this field, the main of which being possible contamination of the ancient genetic material with contemporary DNA. The state-of-the-art DNA sequencing technologies make it possible to efficiently resolve the problem, since they give information about the degree of ancient DNA degradation, which is the most reliable criterion for its authenticity. Thus, a system for assessing the data reliability has been elaborated, which takes into account several characteristics of DNA antiquity such as prevalence of relatively short fragments, chemical degradation of nucleotides, and the distribution pattern of chemically modified DNA bases over the sequenced fragments, in particular their clustering at the ends of molecules (Krause *et al.*).

The technological procedures of high-throughput sequencing are considerably less sensitive to being contaminated with contemporary genetic material as compared with high-sensitive variants of PCR used in traditional paleogenetics studies. Therefore, the corresponding results can persuade the most desperate skeptics. This opens up new prospects for studying the DNA of ancient microorganisms and archaic humans.

Any paleogenetic study is destructive by its very nature since isolation of a DNA sample requires destruction of a certain quantity of a paleospecimen (for example, bone tissue). Since these specimens are valuable sources of ancient DNA in themselves, a researcher always has to solve the problem of obtaining maximum information (in this case, a maximally possible amount of informative genetic markers) by minimally destroying the initial specimen. Earlier, DNA extraction from several hundred milligrams of bone powder provided information about the structure of only a small mitochondrial DNA fragment or of a limited set of short nuclear DNA loci. Now modern methods make it possible to obtain an incomparably larger volume of information by analyzing several dozens milligrams of the initial paleospecimen up to a complete genomic sequence of the organism whose remains are examined.

The possibility of a genome-wide analysis of an ancient organism levels, to a certain degree, the informational capacities of molecular genetic assays of ancient and modern DNA samples, which currently is limited only by state-of-the-art molecular genetics, that is by the level of our knowledge about the genome structure and function of a studied organism.

Certainly, in real life researchers may still encounter poor DNA preservation in fossils, excess external contamination, and other problems. Besides, the high cost of operating the equipment, which limits the conducting of serial assays, will be an important hindrance for the majority of Russian research teams in their attempts to use new methods.

Nonetheless, the potential informational capacity of paleogenetic studies using high-throughput DNA sequencing is increasing manifold. So, we can responsibly speak about the birth of a new field in paleogenetics – *paleogenomics*, which studies the genomic structures of extinct organisms. In this respect, the most promising expectations are associated with examining the Pleistocene organisms, ranging from extinct animal and plant species to the representatives of the genus *Homo*.

An illustrative example of the advances in this field is the discovery of a new Altai hominid species, that coexisted with man of a modern physical type, as well as assessment of the contributions of the Neanderthal and Denisova man to the gene pool of the present humankind. These discoveries provide a new view of one of the most intriguing evolutionary phenomena, the origin of man. We have a long way to go yet. For example, the long-range collaboration program of the Institute of Cytology and Genetics and the Institute of Archaeology and Ethnography in Novosibirsk, which is to be implemented in the nearest future, is going to estimate the contribution of these hominid species to the gene pools of ancient and contemporary people.

Work with paleospecimens at the Interinstitutional Sector of Molecular Paleogenetics with the Siberian Branch of the Russian Academy of Sciences is performed in strict compliance with the corresponding international standards

High-throughput DNA sequencing methods will also encourage the studies of later periods in human history, from the Neolith to the Middle Ages. Several topical research directions, such as reconstruction of race- and ethnogenetic processes, animal and plant domestication, as well as the emergence and spreading of human pathologies will also get a stimulus for their development.

Combining the advantages of paleogenetics (a direct study of the genomes of ancient organisms) and modern molecular genetics, which uses massive analysis of a large number of informative genetic markers, will raise archaeology to a new level regarding the reconstruction of the human past as well as the ancient human environment.

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M. V. SHUNKOV

The DENISOVA CAVE — EVERYTHING CHANGES, *but nothing disappears*

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Key words: pleistocene, paleolith, paleogeography, paleontology, paleoecology

The Denisova Cave in the Mountainous Altai (Gorny Altai) - a unique Paleolithic monument and the most ancient inhabited cave of Siberia – has enjoyed well-deserved popularity for quite some time. The stream of inquisitive people never dries up: local residents, tourists, reporters, not to mention archaeologists and other scientists, from geologists to paleontologists. This spring, however, the cave became world famous thanks to the genetic analysis of the human remains found in one of its galleries, which showed that 50,000 years ago the cave was populated by hominins of a previously unknown species, more ancient than the Neanderthals. Since that time both the cave and the science and research camp of the Novosibirsk Institute of Archaeology and Ethnography, SB RAS, have turned into a major attraction for tourists and journalists including the famous "National Geographic." "SCIENCE First Hand," which has published many time the authors' materials about the achievements of Siberian archaeologists, made no exception. The purpose of the current publication is not only to tell the readers about the multi-year research conducted in the Anui Valley but also to introduce them to the people working there – today's "inhabitants" of the famous cave

Omnia mutantur, nihil interit.
(Everything changes but nothing disappears).
"Metamorphoses" by Ovid

The Denisova Cave – a research site of the Novosibirsk-based Institute of Archaeology and Ethnography (IAET), SB RAS, in Gorny Altai – is 20 years old. The Denisova Cave – a unique archaeological site – is about 300,000 years old. In ancient times, a hidden cavern formed in the interior of the Anui ridge; gradually it widened and deepened under the influence of water flows. When the river valley became deeper, the cave came out into the open.

Today, the river flow runs about thirty meters below the cave entrance, while in the time past it used to be right at the foot of the ridge and flooded the cave during high-water season. The cave remained uninhabited for some time and then, for almost 280,000 years it became a home, first for animals and later for man.

The cave "opened" for the scientific community in 1977, when the well-known paleontologist N. V. Ovodov, at the instruction of the head of the Siberian school of archaeology Academician A. P. Okladnikov, explored the cave for the first time. Two four-meter-deep test pits yielded a rich archaeological material: fragments of ceramics, bone and bronze artifacts, numerous stone tools and flakes. All these findings proving that the cave had been populated since the Paleolithic times became a big event in national archaeology.

During the following field seasons, IAET SB RAS teams studied the cave, regularly discovering new layers of deposits. Rich with artifacts, they uncovered a true chronicle of humankind, from the Middle Paleolith to Middle Ages. It became clear that the Denisova Cave was a unique archaeological monument, second to none in North Asia. It was decided to build a research camp on the bank of the Anui River.

There are no little things for archaeologists

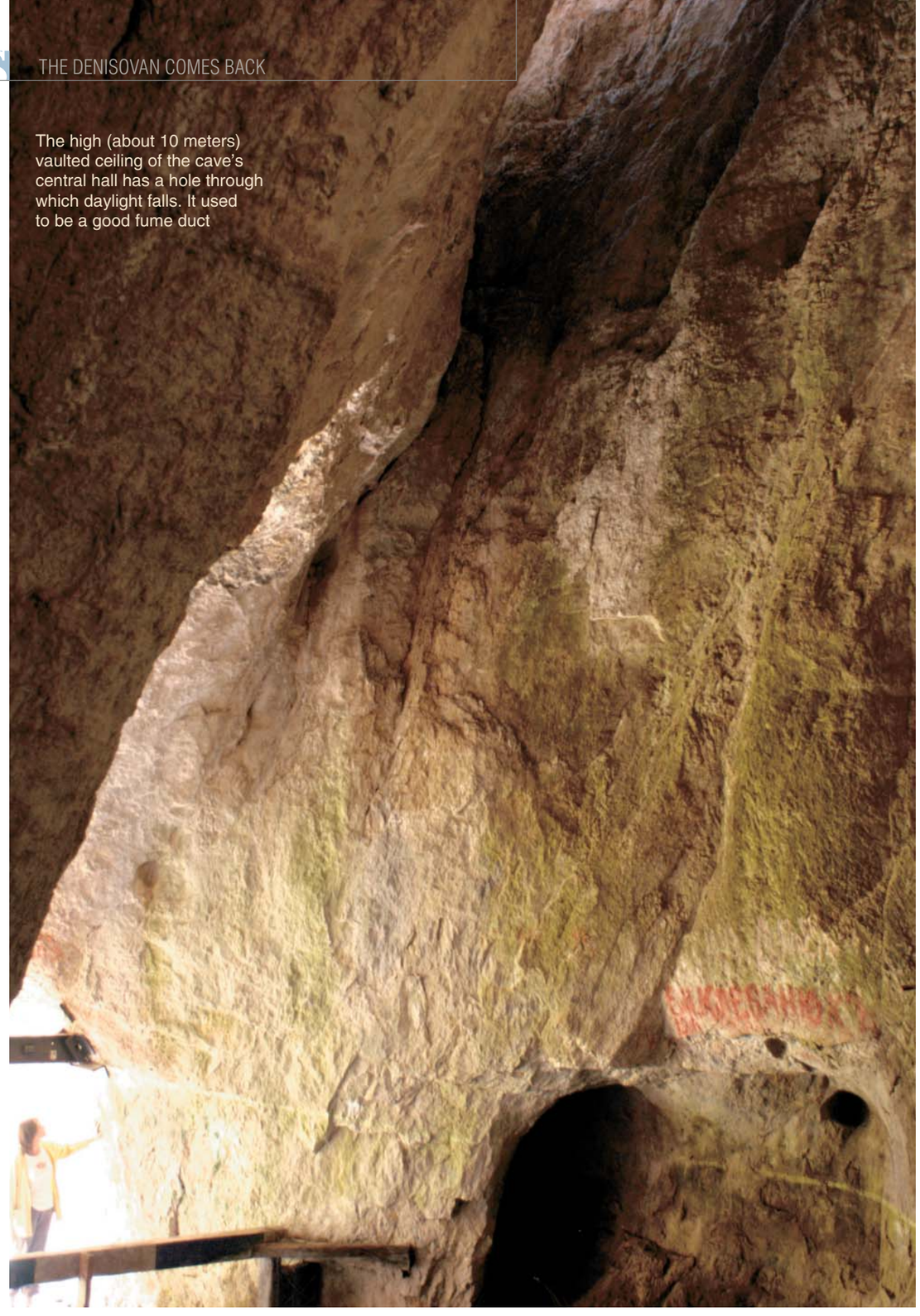
Archaeologists' work in the field is not an easy thing and not nearly as romantic as it might seem at first glance. Their main "scientific" instruments are entrenching tools. The stationary research done in the Denisova Cave successively opened loose deposits in the central hall, in the area in front of the entrance and in the estuarial zone of the southern and eastern galleries. A measure of the scale of the field work is the depth of the dig, which in the central hall is 6.5 meters from the so-called "zero" line showing the deposits level at the beginning of the excavations.

The first house of the Denisova Cave science and research camp was built in 1986. It houses a laboratory and living quarters. Sometimes tourists misled by the sign look for the entrance to the cave here

The Denisova Cave is the most ancient inhabited cave in North Asia. Today, the entrance is 6 meters high but not so long ago its height was one-third of what we have now, and the trail approached the very foot of the ridge (*photographed by the author*). The cracked ledge hanging over the entrance was destroyed for safety reasons by point explosions; in the area in front of the entrance, digs were carried out, and the entrance to the cave was equipped with a timber flooring (*above*).
Photographs by S. I. Zelensky and from the archive of the IAET SB RAS (1983)

The work is performed carefully and methodically. The surface designed for digging is marked out using a theodolite into squares a meter on a side. After that, archaeologists pick out successive layers of soil with the help of knives and brushes to the depth of about 5 centimeters.

Large findings are photographed in situ, and their location is recorded. The head of the dig – there is such a position! – writes down the data in the log, puts



The high (about 10 meters) vaulted ceiling of the cave's central hall has a hole through which daylight falls. It used to be a good fume duct

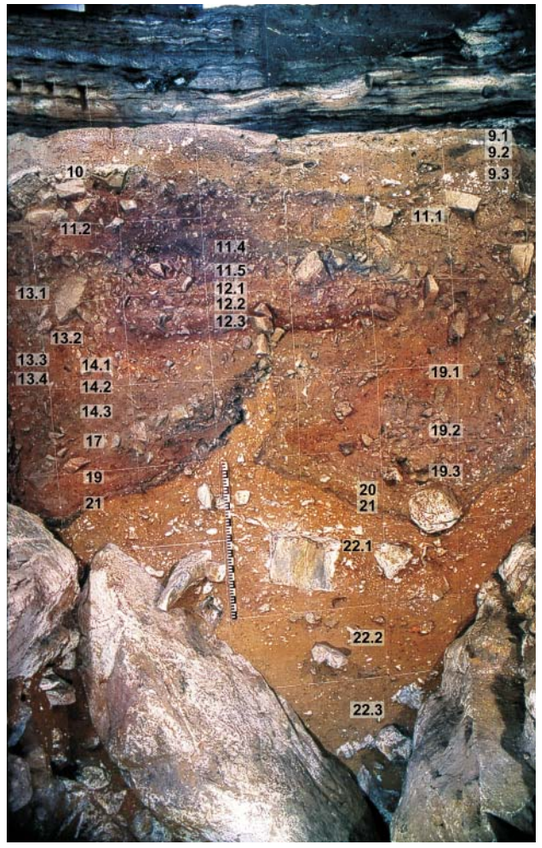
HERMIT DIONYSIUS, A BLACK SHAMAN AND A WHITE VIRGIN

Legend has it that the cave got its name in the late 18th c., when for many years it became home to hermit Dionysius, an Old Believer. He was a spiritual advisor for the Old Believers of the nearby villages, who used to visit his cave cell to receive blessing and advice.

The Altaians call the cave Ayu-Tash (Bear Stone); their hoary myths tell of a powerful Black Shaman who lived in this darkness and could turn into a huge bear ...

There is another sad and beautiful legend associated with the Deniska, which appeared in the neighboring villages right after the Russian Civil War (1917—1923). It tells us about a White Virgin, a desolate young beauty, who hid forever in the cave galleries not to cast in lot with a hateful fiancé.

There is more in this cave than meets the eye... The philosopher N. K. Roerich, who visited it during his Altai expedition back in 1926, noticed a special energy field present in the hollow emptiness. In his draft travel notes, he wrote, "Some pleasant feeling that filled my conscience when I was in the cave did not leave me for a very long time." ***From: (Isupov, 2009)***



There are 22 lithographic layers in the Denisova Cave deposits, 8 of which belong to the Holocene (from 11,000 years ago to modern time) and 14, to the Pleistocene (1.8 million — 11,000 years ago). The most ancient findings from the 22nd layer are 280,000 years old and refer to the early stage of the Middle Paleolithic. The bone remains of *Homo sapiens altaiensis* were discovered in the 11th layer (30,000—50,000 years ago), where typical Early Upper Paleolithic objects appear

the findings into special packets and marks them indicating the layer, square and layer of the dig. The dug out soil is put in buckets, marked and passed for washing.

The buckets filled with deposits are brought down to the river. Successive washings through the screens of different mesh size produce "concentrate," which is sorted out by fractions and sent to a laboratory having all the things needed for work: a microscope, chemicals for express analysis and a computer.

All the material collected is carefully cleaned, sorted and measured. Those who explore the Paleolithic culture have no such notion as "archaeological garbage." Everything is of interest: soils, flints, tiny animal bones. The things unclaimed today may prove to be of huge scientific value tomorrow thanks to new methods. All the material dug in the Denisova cave is carefully stored in the institute.

One man is no man

What is unique about the multilayered deposits of the Denisova Cave is that they are well preserved and easily stratified within the system of geological sediments, which ensures quite an accurate dating of the artifacts contained in them. To date the findings more precisely, radiocarbon, geomagnetic and thermoluminiscent testing is used.

Throughout the sequence, the archaeological material is accompanied by numerous organic remains: plant pollen, fossil clamshells, and bone remains of birds, small and large mammals. This rich material gives the researchers a most rare opportunity to reconstruct the environmental

Archaeologists are like restorers: just one slip-up, and valuable information may be lost forever. People working in the cave are equipped with nothing but a knife, a brush and a children's sand spade

and climatic conditions in the vicinity of the cave existing in those distant ages when ancient people lived there.

Since the very beginning, the study of the Denisova Cave, similarly to the studies of other Paleolithic sites in Altai, has been interdisciplinary. Side by side with archaeologists, there worked scientists specializing in a wide variety of natural disciplines: geologists, paleozoologists, paleobotanists, paleopedologists, and petrographers. Academician A. P. Derevianko managed to collect a strong research team whose skeleton staff included, among others, paleozoologist A. K. Agadzhanian from the Paleontology Institute RAS, paleobotanists

The total area of the cave is 270 m². Branching off from the central hall is a system of galleries: the eastern and southern narrow dark galleries go in the interior of a karst mass, where they are completely blocked by loose deposits. The third gallery leads to the site in front of the entrance. *The photograph* shows a dig in the eastern gallery of the Denisova Cave. *Photographed by S. I. Zelensky*

Stretching from the cave to the opposite bank of the Anui are two cables – an improvised rope way used to transport the valuable material down to the river for washing, screening and sorting.
Photographed by S.I. Zelensky

L.M. Malayeva and N.S. Boliakhovskaya and geologist V.A. Ulianov from Moscow State University. Every year scientists from the capital come to the Anui Valley to be directly involved in fieldwork.

Examining the plant spores, pollen, and seeds contained the cave deposits, paleobotanits determine the species involved in ancient plant associations. For instance, they have discovered that hundreds of thousands years ago in the environs of the cave grew oaks, hornbeams, elm-trees and other broad-leaved species exotic for the modern Altai flora.

The bone remains help to reconstruct ancient fauna. For example, scientists have wondered for long whether mammoths had lived in the vicinity of the cave. Among the discovered tens of thousands of bone remains attributed to various animals, there are a just a few that belong to the mammoth. Today, paleontologists are sure that virtually all of these bone remains are tooth enamel sheets and tusk fragments. Evidently, the ancient man found them beyond the Anui Valley and brought them to the cave to make decorations.

The main production activity of the early man was making stone tools. Therefore, for over 15 years archaeologists have been collaborating with a specialist in mineralogy and petrography of Novosibirsk State University N. A. Kulik, whose research has reconstructed a complete picture of the development of the raw materials base of the early stone industry.

In the primeval valley of the Anui

The availability of a stable raw materials base for tool production in the Anui basin was a major attraction of this area for the early human community. This, however, was not the only advantage: of great value were the unique environmental and climatic conditions and the surrounding plant and animal world.

Pleistocene, which encompassed all the main events of the most ancient human history, is often referred to as the Great Ice Age. It includes several ice periods alternating with interglacial warmings. The last ice period in Siberia – the Sartan Ice Age – began about 24,000 years ago. It was preceded by a long period of comparative warming. It was during this epoch, about 50,000—30,000 years ago, that the girl whose nail-bone was found in one of the Denisova Cave galleries lived. The finding suggested the existence of a new hominin species, Homo sapiens altaiensis.

The climate at the time was quite cool (the average January temperature was –6.5 °C, and the average temperature of July was 18—21 °C), though the absolute minimum did not go below –35 °C, and the temperature in May and September did not fall below zero.

By that time the once rich forest vegetation of the valley had shrunk, giving way to steppes, grasses, bushes and meadows. The small forests were mostly made of fir mingled with cedar and pine. The thermophilic broad-leaved tree species, which used to be common representatives of the Altai flora, had virtually disappeared.

The spreading of the areas with a thick herbaceous layer resulted in an increase in the number of hoofed animals: the primeval bison, horse, Siberian red deer, argali, Mongolian gazelle, and yak, as well as the carnivores, hyena and wolf. Rodents, especially rodent-moles, proliferated. Among the birds naturally domineered the species typical of open landscape.

The laboratory has all the things needed for work: a computer, a microscope, and chemicals for express analysis. The material collected here is carefully cleaned, sorted, and measured. *Photographed by S.I. Zelensky*

On this occasion, toothbrushes are a laboratory instrument: they are used to clean off ground from the archaeological artifacts. *Photographed by S.I. Zelensky*

Near the cave you can come across edelweiss, a well-known inhabitant of the subalpine mountain zone

The Denisova Cave formed within a block of Silurian bioherm calcerous rock that appeared about 430 million years ago, when the Altai territory rested under a warm sea. Witnesses of the epoch are trilobite fossils

Further worsening of the climatic situation deriving from the global drop in temperature would lead to the formation of local glaciers on the northern slopes of the ridges surrounding the Anui Valley and expansion of the snow belt. Dark coniferous forests would be forced out to the lower levels of the valley, and the mountainsides would be covered with grass meadows. Dominating among small and large mammals would be the representatives of the mountain-steppe groups: the high-mountain vole, steppe lemming, long-tailed souslik, as well as Siberian goat, hyena, dzeren (Mongolian gazelle), saiga, and argali. The local mammal structure would easily accommodate the Arctic fox, a typical representative of the tundra biotopes.

The next warming would only occur many millennia later. It would mark the start of the Holocene – a new geological epoch, which is 10,000 years old.

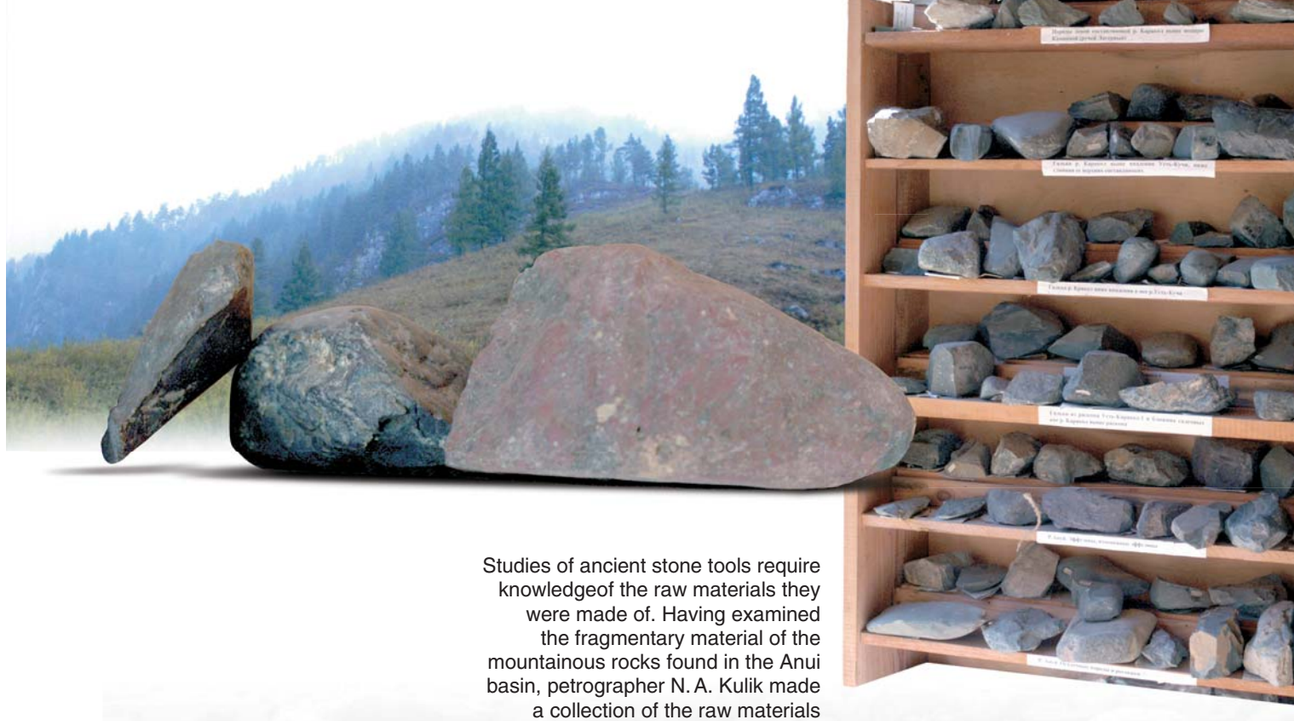
Altai shelter

Summing up the material obtained from studying the multilayer deposits of the Denisova Cave, one may state that from the first appearance of man in the Anui River basin and during the whole period of his development the environmental conditions were exceptionally favorable as compared with the rest of North Asia. The North-Western

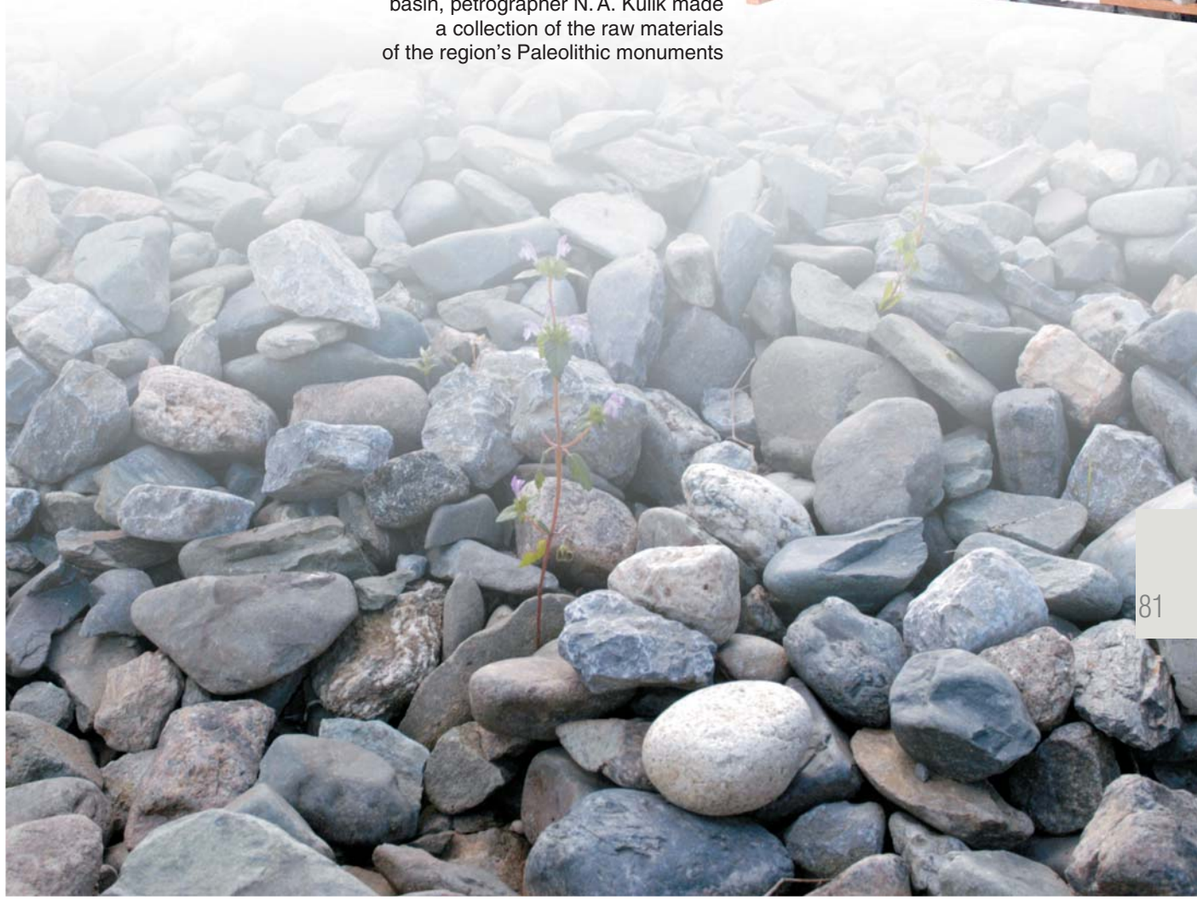
Judging by the stone tools discovered in the cave, the stone processing techniques developing throughout the entire period of the Paleolithic man's life here relied on the same raw material base. This was mostly pebbles and boulders of the sedimentary and volcanic rocks of the Anui and its tributaries' channel deposits. Volcanic rock was preferred thanks to its high strength. For example, about half of all stone tools are made of the effusive, though it makes up only 10% of the pebble raw material.

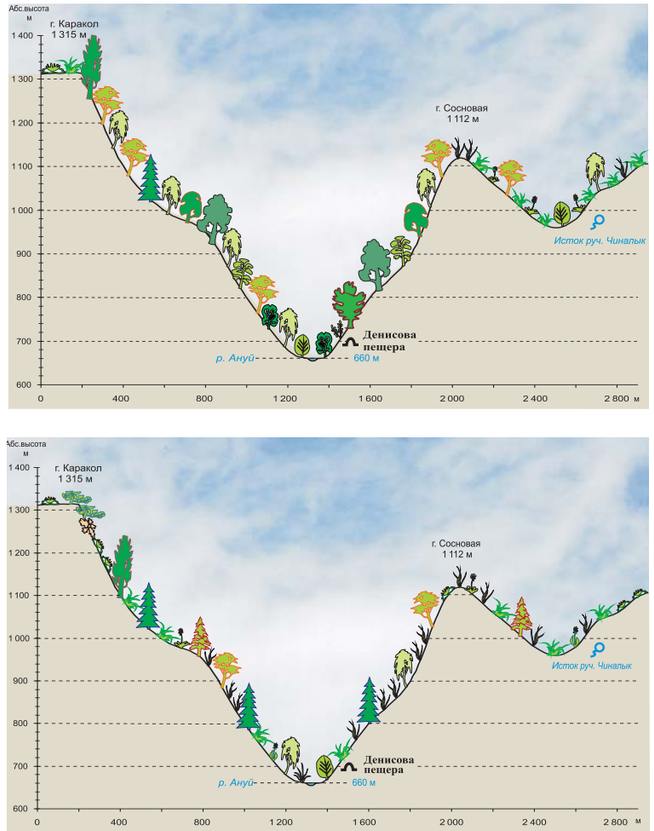
In comparison, sedimentary rocks are much softer, more fragile and anisotropic (their strength is directionally dependent). When cleft, either along natural lines of division or along cracks, they form many fragments. A proof of that is a multitude of pebbles in the shape of bars and parallelepipeds. As these shapes of sedimentary rock fragments are quite monolithic and homogeneously strong, they make a good raw material for tool production.

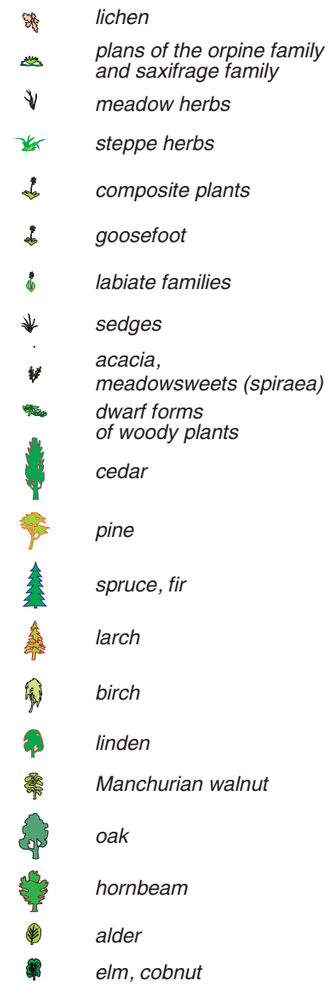
The early man needed to take into account all these properties of pebble raw material, and the ancient artisan intentionally chose the strongest and most homogenous pebbles among a great variety of lookalike pebbles with different petrographic properties. Interestingly, his choice was virtually infallible, as the results of archaeological and petrographic examination show



Studies of ancient stone tools require knowledgeof the raw materials they were made of. Having examined the fragmentary material of the mountainous rocks found in the Anui basin, petrographer N. A. Kulik made a collection of the raw materials of the region's Paleolithic monuments







Vegetation of the Anui Valley during the warmest interglacial period of the Pleistocene 240,000—180,000 years ago (*above*) and in the coldest period 20,000—18,000 years ago (*below*). *From: (Agadzhyanyan, Shun'kov, 2009)*

Altai was in fact a special refugee zone, which became a shelter for many animal species, including humans.

Thanks to the contrasting structure of the mountainous relief, the Anui Valley was protected from the active influence of ancient glaciers, which developed high in the mountains. Neither the surroundings nor the plant or animal world show any traces of the sharp changes unfavorable for humans, which were recorded in the Siberian plains during the cold periods.

To this we can add the natural complexity of the environment with various landscapes, from forests to meadows and mountains, found side by side. The valley itself can narrow to a canyon or expand to a steppe, with true mountainous taiga growing along the anastomosing branches of the river. The Denisova Cave is located in the narrow, canyon-like part of the valley, offering a shelter secured from any side.

During the hunting season, the ancient man could go to the Karakol mouth, where animal migration paths crossed and the area was well within view for many kilometers. Besides, the open plain was "near at hand" – just 100 kilometers away, which the ancient man could cover in two days. And that was a different climate with a different wildlife... To this effect, the Anui Valley was a special "contact zone" between different natural landscapes and communities, which was bound to attract the early man.

As consequence, the unique combination of favorable environmental conditions allowed the human community to reach an unbelievably high development level, and testifying to it is the fact that the Upper Paleolithic period started here earlier than in Europe.

The many-millennia-old layered structure of the Denisova Cave formed in various climatic environments. The discovered plant and animal remains have allowed the researchers to reconstruct the natural conditions in different epochs and trace climatic variations.

We can distinguish several stages in the natural conditions development in the Anui Valley. During the initial stage, the warmest interglacial period (240,000—180,000 years ago), forest landscapes prevailed. Northern slopes were overgrown with mixed pine-birch forests, and ridge tops were crowned with cedar and spruce whereas at the foot of the mountains, in well warmed areas, grew broadleaved trees like hornbeam, elm, linden and Manchurian walnut. The southern slopes of the valley were covered with wild grasses. Along the Anui streambed stretched fringe groves of alder trees, and the banks were overgrown with willows and currants.

Later, owing to the global drop in temperature during the Upper Pleistocene, the forest vegetation of the valley shrank giving way to steppes, grasses, bushes and meadows. By and by, broadleaved species of trees disappeared.

Further cooling down, with the lowest temperatures occurring 20,000—18,000 years ago, led to the formation of local glaciers on the northern slopes of the ridges and expansion of the snow belt. Dark coniferous forests (mostly spruce and cedar) were forced out to the lower levels of the valley while the share of grassy plants reached a maximum. The mountainsides were covered with grassy meadows, and the rocky, well warmed slopes developed short-grass dry-steppe complexes of briar, barberry, pea shrub, etc. In the upper stories of the valley altiplain vegetation formed (bunchgrass herbs, labiates, short spiraea typical of rock streams, etc.)

Living and working at the Deniska*

Today, in the third millennium AD, the unique Denisova Cave still lures many. The stream of curious people – local residents, tourists, reporters – never dries up... But the main "inhabitants" of the cave are still archaeologists.

The cave has been studied for over 30 years. It all began from a tent camp. In 1986, the first house was built, which had living quarters and a laboratory. On the iron rods of the bridge across the rapid Anui there is a date – 1990 – marking the start of intense construction of a science and research camp. It was during the 1990s, the time not easy for science and country as a whole, that the main living, research and maintenance premises were built.

The construction was mainly done under our own steam: research workers, drivers, photographers and scientists dug trenches, laid pipes, and erected houses... The work was done quickly, at high quality standards and with minimal costs. This is not surprising as archaeologists, because of the nature of their work, can do anything: organize a dig site, set up camp, and feed people... Today, the research camp is a small settlement with modern conveniences having everything necessary for living and working: dwelling houses, laboratories, canteens, baths, a laundry and a truck park.

Deniska, as the researchers call their expedition home, is the pride of our research institute, the apple of its eye. It has a special atmosphere, which shows in social relations, attitude to work and attitude to the environment. If you take a walk around the camp, you will not find a single stub or candy wrapper: they don't litter here not because this is prohibited but because this is not done.

There are no bystanders in this united team, even though up to 300 people come here just in one season! Typically, the archaeological excavations involve, in addition to the institute's staff, undergraduates, high schoolers and volunteers. Digging is hard work, both physically and psychologically – it is not easy to work without letup in a cold cave eight hours a day, picking out with a knife layer upon layer when the sun is shining and river lapping a stone's throw from you. No one is forced or coaxed to come here – people come with their heart and not because they have to.

For many years, the archaeologists have been working closely with the teachers of local schools (including schools based in the town of Biysk). Those willing to work are many, so they undergo a rigorous selection, and only the most reliable, hardworking and responsible get an offer. It happens very rarely that somebody cannot take it and leaves.

* The affectionate-diminutive of the Denisova Cave

This cooperation is many years old; it continues from generation to generation. On the one hand, the station has full-time employees; on the other hand, there is an experience of working together with newcomers towards a common goal, when the young get the valuable skills of communicating in large teams. If a dozen years ago the parents were doubtful about letting their children go to the Deniska, today they feel easy about it. Many of the teachers who have worked at the dig in their time currently run archaeology study groups at schools and bring their students here.

Today, our archaeology station is a kind of a visiting card of North-Western Altai. There is no problem here with popularizing science and strengthening the status of researchers – life itself has solved these topical problems, and good neighborly relations with local residents and administration help to deal with pressing challenges.

Archaeological works, however, is just one area of the many activities conducted at the Deniska. Recently, organizing scientific events has been acquiring increasing importance.

In the early 1990s the first premises of the science and research camp were built including several houses for guests on the left bank of the Anui (*photo on the right*). Today, this is a comfortable research town, a venue for scientific symposiums and conferences.
Photo from the camp's archive

SCIENCE FIRST HAND https://scfh.ru/en/papers/the-denisova-cave-everything-changes-/ June • 2018 • N 2 (49)

Frequent visitors here are participants of big national and international scientific conferences and symposiums. Services include a specially equipped conference hall, a spacy dining room and houses with all comforts.

Mathematicians, geneticists and geophysicists have held their scientific forums here. And yet, the most welcome guests are archaeologists. Archaeology is a very particular science: researchers need to see everything with their own eyes, study the structure of geological deposits by themselves, and hold the artifact in their hands...

In recent years, a few interdisciplinary symposiums dedicated to Paleolith have been held here, and their participants had a chance to get familiarized on the spot with the research results of the Novosibirsk school of archaeology and to see that the scale and magnitude of the Paleolithic studies conducted at the Denisova Cave meet the highest global standards.

The editors thank S.I. Zelensky, M.T. Sapronova, and N. Shvedova for their help with the publication

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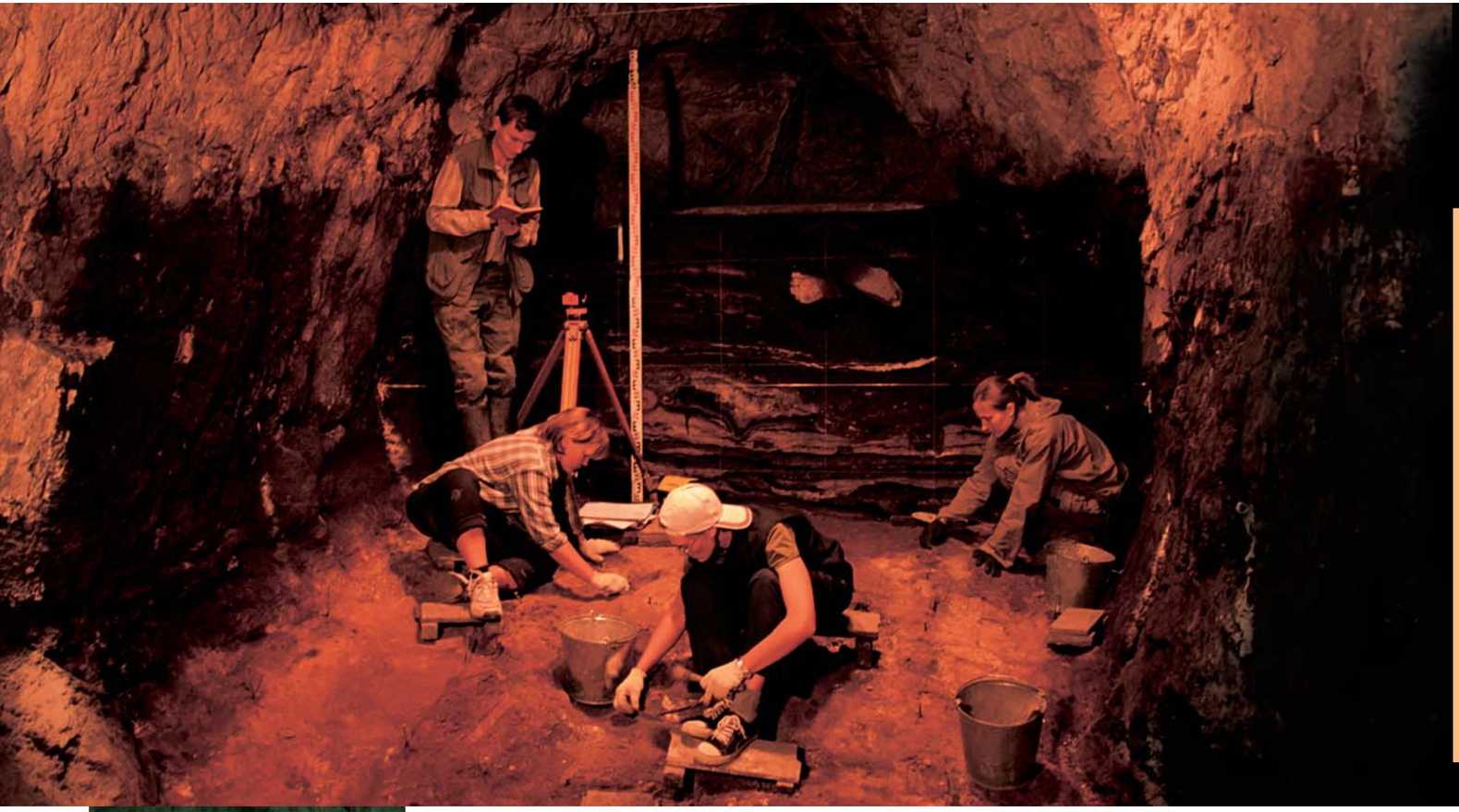
In summer 2007, an outstanding physicist, Nobel laureate Academician J.I. Alferov came to the Denisova cave research camp. He is one of the many celebrities who has paid a visit to the dig. *Photographed by S.I. Zelensky*



MIKHAIL **SHUNKOV**

The GOLDEN section of the ANUI

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Deputy Director of the Institute
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Numerous fossil traces of primitive man have been found in many regions of the Old and New World. Archaeologists study these traces and from this study get an idea not only of the place of the origination of man as a biological species in the course of evolution, but also learn about possible paths of formation of primitive populations on the Earth, as well as about the primary structure of human society and its interaction with the natural environment.

Judging by archaeological finds of the Paleolith, i.e., the early Stone Age, the inhabited part of the earth was peopled non-uniformly. It is possible to distinguish along ancient migratory ways some relatively localized centers from which gradual spread to contiguous regions occurred. From this point of view, particularly attractive were regions located at the junction of large geographical regions on the archaeological map of Eurasia. Southern Siberia, particularly the Mountainous Altai (Gorny Altai), is one of those regions as it connects North and Central Asia. Initially, the primary settling of the area probably occurred due to a northern wave of migration of the African *Homo erectus* (upright man) via the Middle East, West and Central Asia about 900–600 thousand years ago.

Archaeologists at work in the eastern gallery of the Denisova Cave. *Photo by S. Zelinsky*

Leaf-shaped point from the Ust-Karakol site is a multi-purpose weapon of a primitive hunter. *Photo by A. Postnov*

The pride of the Institute of Archaeology and Ethnography, SB RAS, a research camp near the Denisova Cave in the Anui Valley in the Altai. *Photo by M. Shunkov*

Everything, up to the minutest details, is significant in archeology. Professor A. K. Agadjanian, The head of the Laboratory of Mammals at the Institute of Paleontology RAS, Moscow, and his assistant are investigating the ground of the cave on the bank of the Anui.
Photo by S. Zelensky

The Altai proved to be a real Siberian treasury of the most ancient archaeological finds of the Paleolith period, though serious study began relatively recently, in the middle of the 20th century. As a result of systematic archaeological investigations carried out by the Institute of Archaeology and Ethnography, SB RAS, under the guidance of Academician A. P. Derevyanko, over the space of several years, a number of unique settlements of the Early Stone Age located in karst caves and river terraces have been discovered. Out of all this natural archaeological exposition, the finds in the Anui River Valley in the northwest of the Altai deserve the greatest attention.

Settlements of the primitive man, gatherer and hunter, were located conveniently in places with abundant plant and animal life. The cozy narrow river valley in the upper part of the Anui River protected by mountain ridges met these requirements perfectly.

The history of the study of the most ancient inhabitants of the valley began in 1959 with the discovery of a few flint flakes and petrified bones of large animals in a cave in the vicinity of the settlement of Iskra. Twenty years later, on the initiative of the outstanding Siberian archaeologist A. P. Okladnikov, a purposeful search for Paleolithic evidence in the caves of the Anui Valley began. As a result, several unique sites, among them the Denisova Cave, one of the main objects of the Altai archaeology, were discovered.

Bone ornaments of the Paleolith epoch from the Denisova Cave.
Photo by V. Kavelin

Not only caves (Denisova, Iskra, Okladnikov's), which were natural dwellings of the primitive man, but also Paleolithic sites of the open type (Karama, Ust-Karakol, Anui-1–3, etc.), were concentrated in that part of the Mountainous Altai. The uniqueness of these archeological monuments lies in the fact that they are multilayered. The heavy thickness of the multilayer deposits formed by successive deposition of the horizons of habitation of the Paleolithic man keeps the chronicle of the basic stages of the primitive epoch.

In the alternation of strata at the Paleolithic sites, not only archaeological artifacts, such as stone tools, flint flakes, ornaments made of stone, bone, and teeth of animals, remnants of bonfires, and other direct evidence testifying to the habitation of the primitive man were discovered, but also plenty of plant pollen, thousands of bones of big and small animals, and other organic remains. This rich assemblage of artifacts and organic substances helps paleo-ecologists to reconstruct in detail the climate and structure of the biocenosis of the Primitive age, to trace the long process of evolution of the environment that surrounded the primitive man in the distant epoch of the Pleistocene.

The earliest evidence of penetration of the Paleolithic man into the Altai is the Karama site dating back 400–800 thousand years. In red-color deposits of the lower Pleistocene, some large-size pebbles were found with roughly chopped-off sharp edges used as primitive stone implements like side scrapers, choppers, and choppings, which constituted the pebble-tool industry typical of the early Paleolith epoch.

In that age, the climate in the Anui Valley was mild and favorable for the life of the primitive man. The occurrence of such deciduous species as elm, hornbeam, linden, maple, and oak, exotic for the contemporary flora of the Altai, in the birch and pine forests of the region testify to it. Numerous and diverse fauna inhabited the rich vegetation of the forests. Small and medium-sized mammals such as badger, marmot, hare, etc., made a significant part of the diet of hunters of the time.

As for large prey, primitive men used to make a living by gathering the remains of meals of such predators as hyenas, wolves, or bears.

About 300 thousand years ago a new period of early ancient history, the epoch of the Middle Paleolith, began. At that time the primitive man started to populate caves actively. The most ancient dwelling of that kind in the Altai and one of the most ancient in Russia is the Denisova Cave. It is located 15 kilometers from Karama, up the Anui Valley.

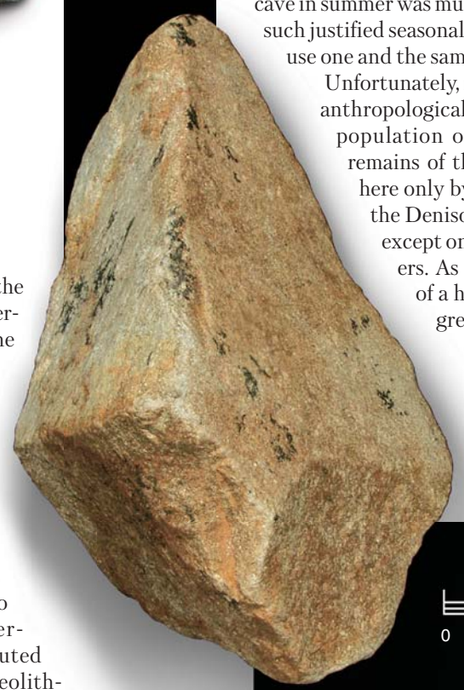
In the central hall of this comfortable dwelling created by nature, one can see some thin successive layers of deposits making up a stratum 6.5 meters thick; this stratum contains information on the development of the natural conditions and human society in the course of the last 280 thousand years, if not longer.

At the time when our distant ancestors chose the cave as their dwelling, the valley was covered with motley grass and grain steppe that served as pasture for diverse hoofed animals (bison, saiga, red deer, and horse), which were the main hunting prey for the Paleolithic man. Pine and birch forests with an admixture of oak, maple, linden, and elm, the natural habitat of roe, maral, and bear, occupied the lower part of the mountainsides. Above, the slide-rocks covered with bush and grass were inhabited by argali and Siberian billy-goat.

A special method of stone processing called the Levallois technique was the main technical achievement of the Paleolithic man. The technique consisted in chopping off large flakes from a specially prepared fragment of the original stone raw material, i. e., the nucleus. As a result, some large plates and spikes with symmetrically sharp edges were shaped that required almost no further treatment; the obtained tools had a thin profile and were very convenient to work with. Technical achievements in splitting stone made it possible to substantially improve the shape of two primary types of implements, the point scrape and the side scraper.

In the subsequent millennia of the Middle Paleolith (120—50 thousand years), the Paleolithic man continued to settle actively the territory of the Altai. In the Anui River basin, the steppe was advancing, which was

Hunting equipment of primitive inhabitants of the Anui Valley. *Photo by V. Kavelin*



Archaic pebble tool from the site Karama

accompanied by the reduction of the forest area. The number and biodiversity of the forest fauna such as the forest vole mouse and arboreal species of rodents, decreased; whereas the proportion of the steppe and meadow species of animals, on the contrary, increased, both of which testify to this process.

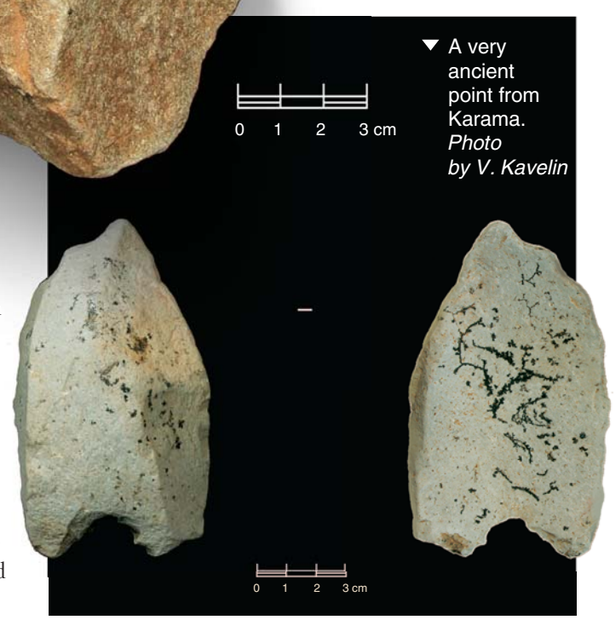
Degradation of the forest ecosystems and formation of extensive steppes and meadows with a thick grassy cover led to increased numbers of large herbivorous animals which constituted the basis of hunting for the Paleolithic man and resulted in the increase of man's activity in the Anui Valley. This is confirmed by a substantial increase in the amount of stone tools in the deposits of the Denisova Cave, as well as by a sharp reduction in the number of bear's bones, the main competitor of man for a comfortable dwelling. Additional evidence of the sharply increased disturbance by man is a ten-fold decrease in the colony of bats in the cave.

It is noteworthy that a great number of bones of the cave hyena, a predator of open spaces, yet incapable of a lengthy pursuit of its victim, were found in the cultural layers of that epoch. A stable population of hyenas could exist only on the condition that the quantity of hoofed animals, including young animals, impaired or sick, was steadily high.

The question arises as to how a hyena and man could share the same dwelling. A hyena is known to need a protected shelter for their cubs in spring and early summer. Man primarily used the cave in autumn and winter as a safe shelter from the cold; whereas during warm seasons he stayed at temporary open-air sites on river terraces that had a good field of vision of spacious hunting territory. Besides, the number of bloodsucking parasites, which increased during the winter period, may have been a solid argument in favor of seasonal resettlement of man from the cave. Another point is that the ambient temperature in the cave in summer was much lower than outside. As a result of such justified seasonal migrations, a man and hyena could use one and the same cave, though in different seasons.

Unfortunately, it is difficult to determine the exact anthropological dating of the Middle Paleolithic population of the Altai mountains since the remains of the fossil hominids are represented here only by several teeth found in two caves, the Denisova and Okladnikov's. All the teeth except one belonged to children and teenagers. As for other bones, only a small piece of a humerus was found, as opposed to a great number of various animal bones.

According to the American anthropologist K. Turner, the teeth that were found have a number of strongly pronounced Neanderthal features that make their



A very ancient point from Karama. *Photo by V. Kavelin*

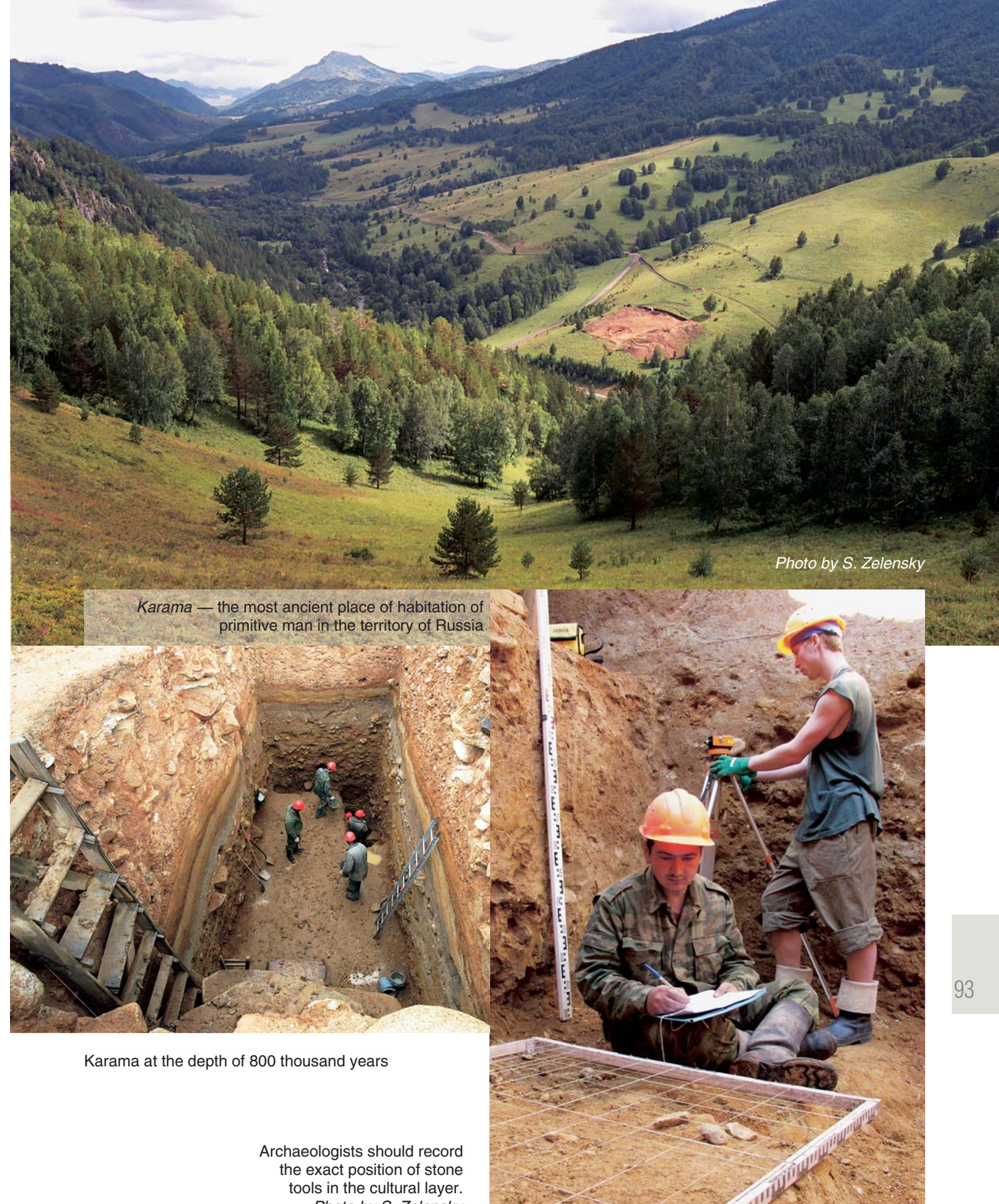


Photo by S. Zelensky

Karama — the most ancient place of habitation of primitive man in the territory of Russia

Karama at the depth of 800 thousand years

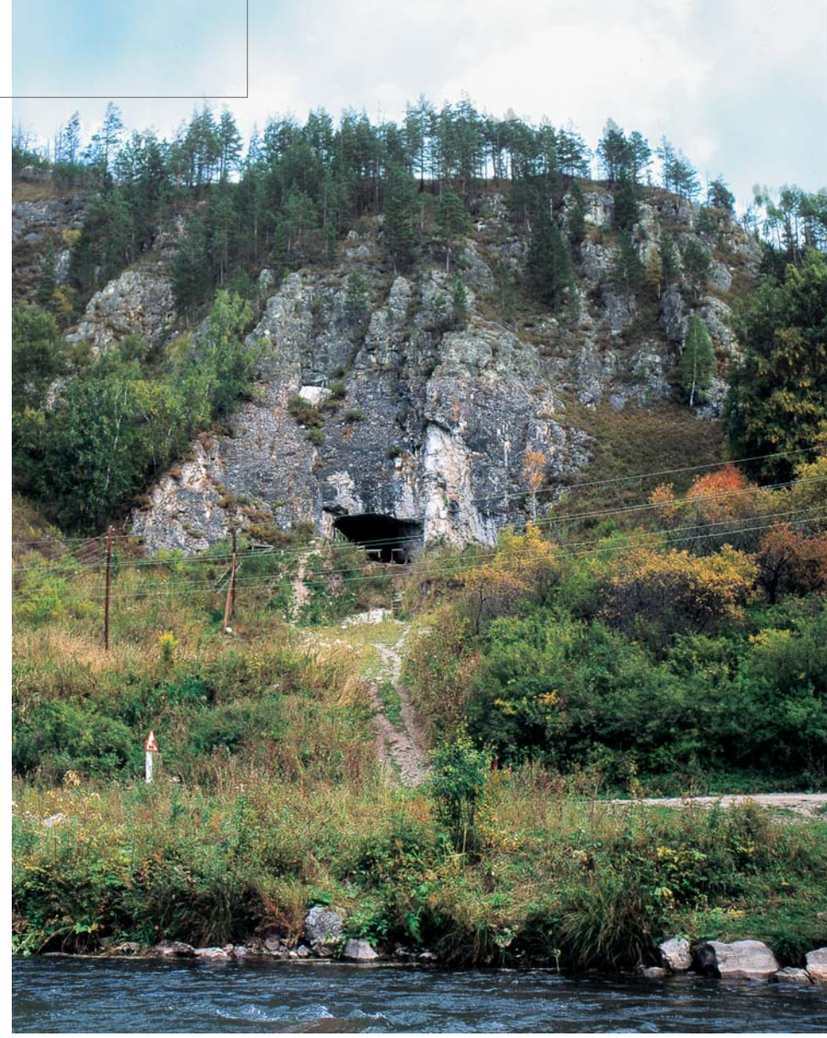
Archaeologists should record the exact position of stone tools in the cultural layer. *Photo by S. Zelensky*

owners closer to the representatives of the European *Homo sapiens neandertalensis*. However, Russian anthropologists V. P. Alekseev and E. G. Shpakova suggested that, despite some archaic features, they must have belonged to the fossil man of the modern type, the early *Homo sapiens sapiens*.

Judging by the state of incisor enamel of a grown-up man from the Denisova Cave, it can be concluded that the conditions of his existence were relatively comfortable, without any strong physiological stresses due to protracted starvation or chronic diseases.

Assemblages of Paleolithic tools provide the most complete information on the life of the primitive man. The absolute majority of the assemblages of stone tools of the Middle Paleolith found in the Altai Mountains belong to the same cultural tradition and have a set of uniform features. At the same time, they are characterized by different combinations of production techniques, as well as by different types of tools, which allows us to divide them into two basic industrial types. In one group, side scrapers of different modifications dominated, whereas in the other group, points and flakes with sharp thin edges dominated. The causes of this differentiation in stone industries should be sought in the peculiarities of economic activity rather than in the division of the population into isolated groups.

The life of the Paleolithic Man could be said to have proceeded in two dimensions, mostly in caves and at hunting camps in some seasons. As an illustration, the distribution and composition of stone artifacts (assemblages of split stones, tools for working them, and various tools) at the multilayer sites of Ust-Karakol and Anui-3 point to sufficiently regular, though comparatively short-term habitation of men there. In such temporary camps, men manufactured mainly special-purpose hunting equipment, i.e., triangular and leaf-shaped points.



The Denisova Cave is a safe storehouse of ancient history of the Altai region. *Photo by M. Shunkov*

Among the artifacts found in the caves multi-purpose scraping and cutting tools such as scrapers predominated, as well as tools with serrated and notched blades. There were some tools with traces of double-face treatment as well as artifacts manufactured with the classical Levallois technique, though on the whole these traditions were less pronounced than at seasonal camps.

Between 50 and 40 thousand years ago, in the Altai the cultural complex of the Upper Paleolith was gradually formed, on the basis of local traditions.

The beginning of that epoch was marked by a general softening of the climate, expansion of the forested and meadow area, and a high degree of landscape mosaicism, which is confirmed by fauna peculiarity. Argali existed side by side with the Siberian billy goat, woolly rhinoceros, and bison, representatives of different ecological groups. On the whole, natural conditions of the Upper Paleolith were rather unstable, whereas its concluding stage

Detailed study of artifacts in the Denisova Cave. *Photo by P. Labetsky*

A unique assemblage of artifacts of animal bones and teeth found in the Denisova Cave: a — bone needles and awls; b — a very ancient necklace of fox's and maral's teeth. *Photo by V. Kavelin*

A tooth of one of the first Asian *Homo sapiens* is the most rare find in the Denisova Cave

(24—11 thousand years) was accompanied by a progressive fall in temperature. This led to the most pronounced deterioration of the natural environment in the whole period of the Pleistocene. The proportion of herbaceous plants and bushes increased essentially, small forests consisted mainly of dark-coniferous species. Among the animals, cliff and steppe dwellers became predominant; and even the white fox, a typical representative of the tundra, appeared there. Later on, about ten thousand years ago, the climate became milder, forests were restored, and the look of the biocenosis of the Anui Valley began to approach the contemporary one. The holocene, a new geological epoch, began.

The stone artifacts belonging to the latest period the Paleolith testify to a wide production of narrow thin plates with sharp edges that were used as a basis for various special tools. The novelty is a microplate that served as a blade for composite tools. Tools, and ornaments made of bone were yet another innovation. Miniature needles with a bored eye, punches and pierces with rows of circular threads, beads and rings made of mammoth tusks, pendants made of animal teeth, flat bead-rings made of fossil ostrich egg-shell, all of these artifacts were found in the Upper Paleolithic layers of the Denisova Cave. This unique collection of ornaments is not only the richest, but also the most ancient in North and Central Asia.

It is possible to trace the division of the Altai stone industries into two independent traditions already at the early stage of the Upper Paleolith. The first tradition is connected with the further development of the technique of splitting stone into flakes, as a result of which the basis of many tools were large plates. Besides the Altai, such technologies were discovered in a number of other archaeological regions of Siberia.

The other tradition developed the technique of microplate flaking and manufacturing leaf-shaped points. Formation of this technological tradition in the Altai in the beginning of the Upper Paleolith must have given a new impetus to the spread of these technologies from the Southwestern regions of Siberia to the East and Northeast. Successively, this area embraced not only all of Eastern Asia, but also the northern part of the American continent.

Thus, the unique archaeological monuments of the Anui Valley have allowed us to get insight into the

life and world that surrounded the ancient population of the Altai, the population that played an important role in the formation of the primitive inhabited part of the vast Asian region.

Today the Anui Paleolithic complex is the most complete and well investigated in North and Central Asia. Its uniqueness lies not only in the fact that many multilayer Paleolithic sites of various types are concentrated in a relatively small area, with the materials from archaeology and natural sciences complementing each other, but also in the interdisciplinary approach to studying these artifacts.

Though the study of the Paleolithic monuments of the Anui Valley is far from being completed, it is, nevertheless, possible to assert that in the epoch of the Paleolith, the northwestern part of the Altai was a kind of oasis sheltered from active influence of ancient glaciation periods thanks to the structure of its mountain relief. A primitive community whose cultural influence extended to the territory of Northern, Central and Eastern Asia, developed in that favorable natural environment.

Tools of the Paleolithic inhabitants of the Anui Valley.
Photo by V. Kavelin

Drawing by N. Kovalev

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По: Nauka iz Pervykh Ruk, № 1(4), SCIENCE First Hand, V. 1(4)

STONE age WORKSHOP

Since the old times people have encountered intriguing finds, stones of unusual appearance and shape such as retouched pebbles, pointed stone plates, leaf-shaped flints... Russians sometimes called them witch's fingers, or thunder arrows. The theory of evolution and fossil anthropological finds accounted for the origin of the majority of these objects. They were made by the primitive man.

For a long time archaeologists were engaged in studying the external appearance of artifacts that were found; therefore their conclusions concerning those ancient tools were rather speculative and subjective. Eventually, researchers rolled up their sleeves, got down to work and ... made a stone axe. This reconstruction of the activity of a primitive man allowed them to understand how tools were produced in the Paleolith. Having compared the traces of abrasion on the surfaces of simulation models with their ancient "prototypes," archaeologists determined for what purpose and how these tools were used.

The outcome of these archaeological experiments was unexpected. For instance, it turned out that it took our "experienced" contemporary no more than a couple of hours to make a stone axe! On the other hand, the majority of tools that dated back to the early and late Stone Age had hardly any differences in the level of skill and technique of execution. This is something to ponder about...

P. V. Volkov, Doctor of History, expert in experimental archaeology (Institute of Archaeology and Ethnography, SB RAS, Novosibirsk) at work

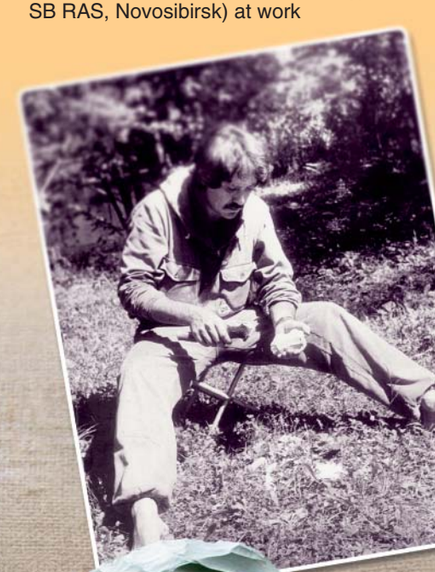

Photo by P. Volkov

Stone tools, bifaces, made by contemporary "skillful hands"

The toolkit of the archeologist experimenter

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"Denisovan comes back"

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The Anui Valley. In ancient times, a hidden cavern formed in the interior of the Anui ridge; gradually it widened and deepened under the influence of water flows. When the river valley became deeper, the cave came out into the open. The Denisova Cave in Altai– a research site of the Novosibirsk-based Institute of Archaeology and Ethnography – is 20 years old. The Denisova Cave – a unique archaeological site – is about 300,000 years old

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