International Geopark Camp for Youth

Educational program of UNESCO Global Geopark

Muskauer Faltenbogen / Łuk Mużakowa

The International Geopark Camp for Youth (IGC) is a biennial educational offer of the German-Polish UNESCO Global Geopark Muskauer Faltenbogen / Luk Mużakowa, internationally known as Muskau Arch. It was launched in 2014 and initially aimed at youth in the age of 13-14 years from all over the world, who were able to participate in the camp of Muskau Arch Geopark in cooperation with a geopark in their home region. During the one-week stay, the participants dived into the unique glacial history and geology of the Muskau Arch on field trips and learned about its wealth of raw materials, the craftsmanship and processing industry that developed from them in numerous practical workshops. In this way, the students were introduced to the history of the region in a playful and artistic way, but also were introduced to the geological conditions that were the basis for this development. The program was rounded off by a wide range of interpersonal activities, during which the international participants were able to get to know each other's culinary and cultural specialties.

Since the successful start of the project under the title "*Art meets Geology*", the IGC has been held with slight modifications two more times under the mottos "*Craft meets geology*" and "*Energy meets Geology*" in 2016 and 2018, respectively. Only minor changes were made to consider the language barrier and to allow the participants to get to know each other better.

Due to the strict Corona restrictions, the 2020 project was postponed for two years. However, the forced break did not remain unused, but the project was adapted to today's circumstances and urgent ecological challenges in a sustainable way. Thus, the IGC could take place once again in 2022 under the motto "*Geology meets geological witnesses of climate change*". The successful core of the one-week stay including workshops, field trips and cultural activities was maintained. However, a small but very informative research project preceded the IGC for a duration of 9-12 months. During that time, the youth group and a supervising teacher did their own research on *'witnesses of climate change'* and how this topic can be applied to a local geopark in their region. Scientific support with field trips and background information was provided by the geopark staff during regular meetings. The whole project and activities during the camp were accompanied by video recordings, which have been compiled into a short movie. By the end of the camp, every group should present their project and prepare a short report in the form of a scientific manuscript.

For future IGC's our theme, i.e. "*Geology meets geological witnesses of climate change*" will be maintained. We will continuously collect the reports of all participating groups and make them available as online to the interested public. In this way, the book will be further enhanced by the participation of different geoparks around the world, looking at different aspects of climate change and different time periods in the history of the Earth.

How to participate?

Firstly, you choose a topic that connects the topic of the IGC with your regional earth history and a member of the supervisory staff. Secondly, you are looking for a 5-person youth working group aged 15 and 16. If a teacher is interested, you can apply for the participation on an informal way – please not more than one-page A4. This paper should include the most important information about a) the topic to be investigated, b) a short introduction of the school, the class and the teacher and c) an introduction of the supervising member of the UGGp‘s staff. After the application’s deadline, the Muskau Arch team will elect the participating schools.

The call for the next IGC in UNESCO Global Geopark Muskau Arch will always be published on the geoparks channels about a year before it takes places.

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Previous participants

Year 2014: Art meets Geology

Geopark Český ráj, Czech Republic

Geopark Bakony–Balaton UNESCO Global Geopark, Hungary

Geopark Muskauer Faltenbogen / Łuk Mużakowa, Germany/Poland

Year 2016: Craft meets Geology

Geopark Bakony–Balaton UNESCO Global Geopark, Hungary

The Holy Cross Mountains UNESCO Global Geopark, Poland

Muskauer Faltenbogen / Łuk Mużakowa UNESCO Global Geopark, Germany-Poland

Year 2018: Energy meets Geology

Pollino UNESCO Global Geopark, Italy

Haţeg UNESCO Global Geopark, Romania

Lesvos Island UNESCO Global Geopark, Greece

Muskauer Faltenbogen / Łuk Mużakowa UNESCO Global Geopark, Germany-Poland

Year 2022: Geological Witnesses of Climate Change

Haţeg UNESCO Global Geopark, Romania

Muskauer Faltenbogen / Łuk Mużakowa UNESCO Global Geopark, Germany-Poland

IV. International Geopark Camp 2022

Warm Period Habitat

- Reconstruction of the mammoth Susi habitat -

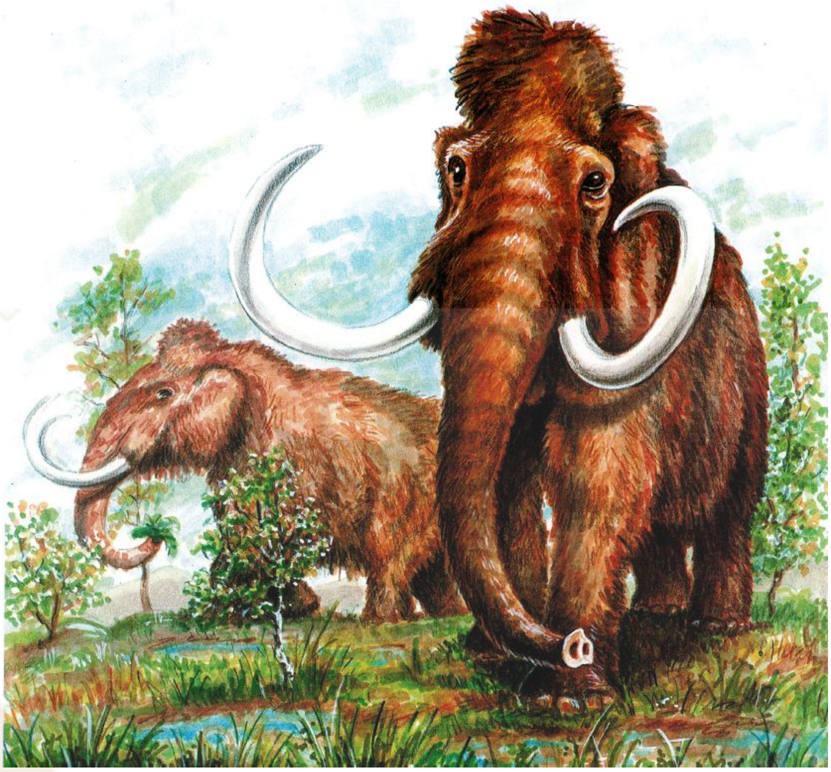

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Table of contents

Abstract: *In the year 1908 there was a remarkable discovery near Klinge 12km east of Cottbus in Germany. A fully preserved mammoth skeleton which is thought to be 115 000 to 126 000 years old. Researchers found out that the mammoth lived in a temperate climate, which was even about 2 degrees warmer than today's weather. This works purpose is to explain the climate and conditions of the mammoth´s time.*

1. Introduction

1.1. Project – IV. International Geopark Camp for Youth 2022

In the summer of 2022, the German-Polish Muskau Arch UNESCO Global Geopark will conduct the IV. International Geopark Camp (IGC). Dedicated youth groups from Germany, Poland and Romania will participate in it. In preparation for the camp, the young participants will work on a project thematically related to their corresponding Geopark over a period of about 9 months.

In the summer of 2022, the international groups will meet in presence for a one week camp on the territory of the Muskau Arch Geopark and compile their gathered research into a book (to be expanded over the next years), which will be made available and distributed to the interested global (geopark) community. The research project of the german participants will be scientifically accompanied by the geoscientific staff of the UNESCO Global Geopark Muskau Arch.

1.2. Topic and research question

The topic addresses a global issue that is the focus of current scientific research and takes place under the theme:

Geology meets geological witnesses of Climate Change

Using the mammoth Susi as an example, we will investigate the habitat of a supposedly cold-age mammal during the Eemian warm period (126,000-115,000 years ago) based on information from the fossil site.

Background:

> *The woolly mammoth "Susi tusk" is the mascot of the Muskau Arch Geopark. It was discovered in 1903 in a clay pit in the village of Klinge. It was a female animal, about*

45-50 years old, with a comparatively small shoulder height of about 2.75 m (mammoth bulls are usually larger than mammoth cows). The mammoth of Klinge is the oldest find of a largely complete mammoth skeleton preserved in Germany. However, it is also the smallest of the eight skeletons known from Germany. Together with numerous other animal and plant fossils, the mammoth has been preserved in deposits of a lake of the Eemian warm period. Among the fossils, which are about 120,000 years old, were various amphibians, reptiles, but also mammals such as beavers and deer. Remarkably, cold-age mammals such as mammoth, woolly rhinoceros or reindeer apparently adapted well to the warm period. The mammoth of Klinge was found in a layer of peat. Scientists have concluded that it drowned in a bog while watching out for a watering place. Humidic acids discolored the bones into dark brownish shade. The accompanying fossil fauna and flora of the mammoth, for example pollen and leaf finds, indicated a climate that was somewhat warmer than today. This find from a temperate climate contradicts the generally held view that the woolly mammoth has the image of being a "giant of the Ice Age" and that its habitat was generally in a cold climate. In the habitat reconstructed according to the circumstances of its find, the mammoth lived in a floodplain landscape in which open waterholes were common and, among other things, warmth-loving birch trees grew.

2. Geological Setting

2.1. Geopark Muskauer Faltenbogen / Łuk Mużakowa / Muskau Arch

The Muskau Arch Geopark has been included in this category since 2003. In 2006 it was recognized as a National Geopark in Germany, in 2011 it became a Geopark of the European Geopark Network, and in 2016 it was finally recognized as a UNESCO Global Geopark. The goals of the park are to preserve the environment, support sustainable scientific development and provide for geoscientific knowledge transfer.

The German-Polish transnational geopark covers an area of 578.8 km² in the states of Brandenburg, Saxony and the Lubusz Voivodeship. The so called Muskau Arch is known as one of Europes most scenic push-end moraines. The 20 km long and 20 km wide arch was formed by the Muskau glacier during the Elsterian ice and is over 340,000 years old.

When the glacier advanced into the area its weight caused the subsoil of sand, gravel, clay and lignite to be compacted to a depth of up to 300m. The unconsolidated rock masses piled up in front of the glacier formed a terminal moraine about 150m above ground level. The moraine was further shaped by fluvial activities during the last ice age, which created an up to 30m deep valley with numerous meanders and terraces.

The glaciotectonic activity brought the precious lignite, clay and sand deposits to the surface, which led to early mining activities and industrial uprise of the region.

2.2. Geomorphology

2.2.1. Glaciers

General:

Glaciers are closed ice masses that move forward according to the slope of the terrain, the structure of the ice, its temperature and mass. The term generally only refers to mountain glaciers. Especially during the ice ages of the Pleistocene, when ice masses in the northern hemisphere reached as far as northern Central Europe they were an important factor of landscape shaping.

Formation:

For glaciers to form, it must be cold enough and plenty of snow must fall. Above a certain height, the so-called ‘snow line’ (depending on the climatic situation), it is so cold that no more rain falls, only snow. Glaciers form when the amount of snowfall exceeds the amount of loss by melting.

Layers:

The colleting basin, is located above the snow line. In this part snow is transformed into ice (the glacier grows). The uppermost layers here always consist of snow or firn (snow that is at least one year old, ice grains stick together).

The ablation area, is located below the snow line. This tongue-shaped part of the glacier is the largest. In the Zehr area, the snow that was formed in the collecting basin melts. The resulting meltwater flows into small streams and causes crevasses or furrows in the ice. The more snow falls, the thicker the firn layer becomes and the ice grains are squeezed tighter and tighter together. This first creates the firn ice and finally the bluish glacier ice, which can become several hundred meters thick. The thicker the ice mass grows, the greater the pressure it exerts. This causes the lower layers of the glacier to move and it begins to flow slowly downward. In the process, it carries rock and debris with it.

2.2.2. Glacial Series

Depositional Formations:

Ground moraine, terminal moraine and glacial stream channel are part of the ice age landscape which, in geology is known as glacial series.

The term moraine is generally used for debris material which is transported and deposited by the glacier. The ground moraine refers to the sediment deposited at the base of the glacier. This material is then removed until it is in front of the glacier, where it is reduced in size by pressure and sinks. This process creates various shapes, such as drumlins. Drumlin comes from English and means shield mountain, indicating its elongated and hummocky nature.

The terminal moraine can occur in different forms. These differ in the way they are formed. For example, one is formed during a glacial standstill, the other during an ice retreat. In both forms, material is deposited at the end of the glacier. The Muskau Arch is a so-called push-end moraine which is a special type of terminal moraine. It was formed by deformation of the underground, mainly due to the net weight of the moving glacier.

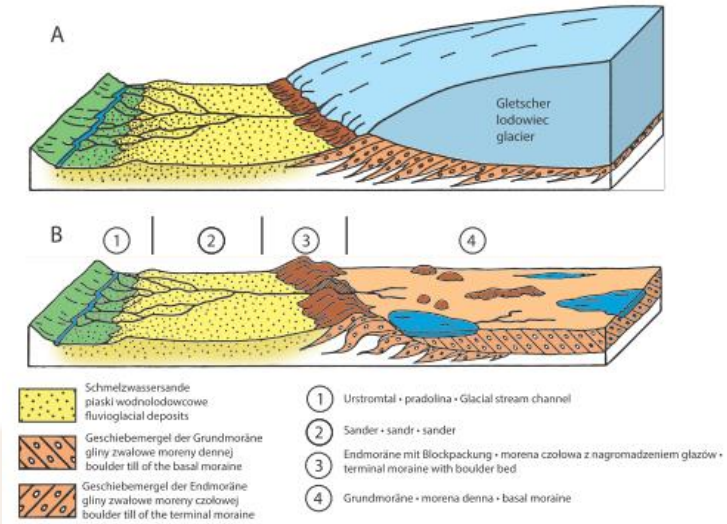

Figure 1: Glacial series (Schröder 2003)

The sander is formed with the help of glacial streams that run through a terminal moraine. The deposited material of the terminal moraine is carried along and deposited on a large area in front of the glacier. The material that is carried along consists mainly of sand, gravel and boulders. In an outwash, the heavy material is logically removed less than the light material. This means that the heavier material tends to stay close to the moraine, and the light material spreads far out.

The glacial valley is relatively uniformly composed of sands and gravels. Finer sands dominate, especially in the upper sections of the glacial valley sediments. The thickness of the glacial valley sediments also varies greatly, but is usually well over ten meters.

When the advance of a glacier pushes together the material lying in front of the ice margin, a push end moraine is formed. Often these consist of previously deposited moraines. They can also consist of components of the until then not glacially deformed bedrock or contain fluvioglacial and glacio-limnic sediments. If the latter is the case, the moraine can be well recognized by the fold-like stratification.

2.3. Formation of the Muskau Arch

Before glaciation:

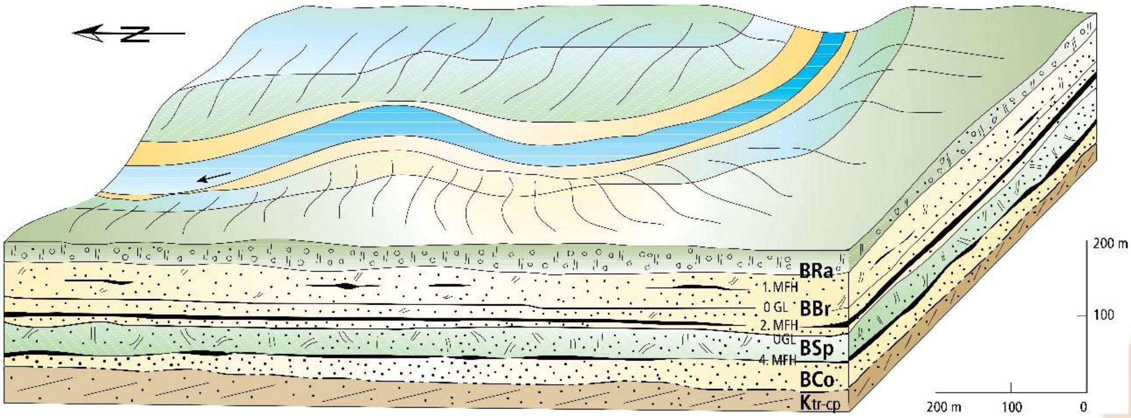

Figure 2: Before glaciation (>340,000 years ago)

The terrain was flat and level, as well as densely forested. The soil layers mostly consisted of sand, clay and lignite. It was populated by various animal species such as wolves.

During glaciation:

Due to its heavy weight, the glacier pushes many different materials in front of it. Due to its mass, it deforms the landscape around it and folds together the different layers of soil. This creates a large and long chain of hills. The glacier was 500m high and reformed the landscape even 270m under the ground level.

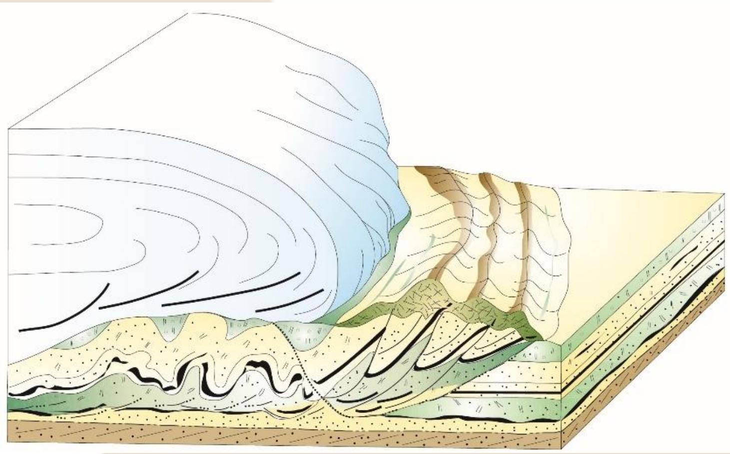

Figure 3: Muskau glacier in action

Melting of the glacier:

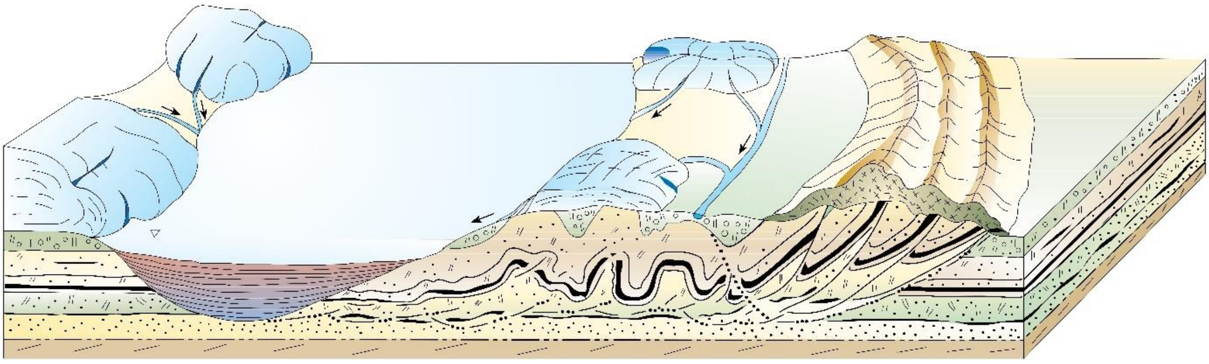

Figure 5: Melting of the glacier

The retreat of the glacier left behind ice dams with meltwater sediments. The materials the glacier brought with it, remain (example: boulders= large stones mostly of Nordic origin).

After leveling:

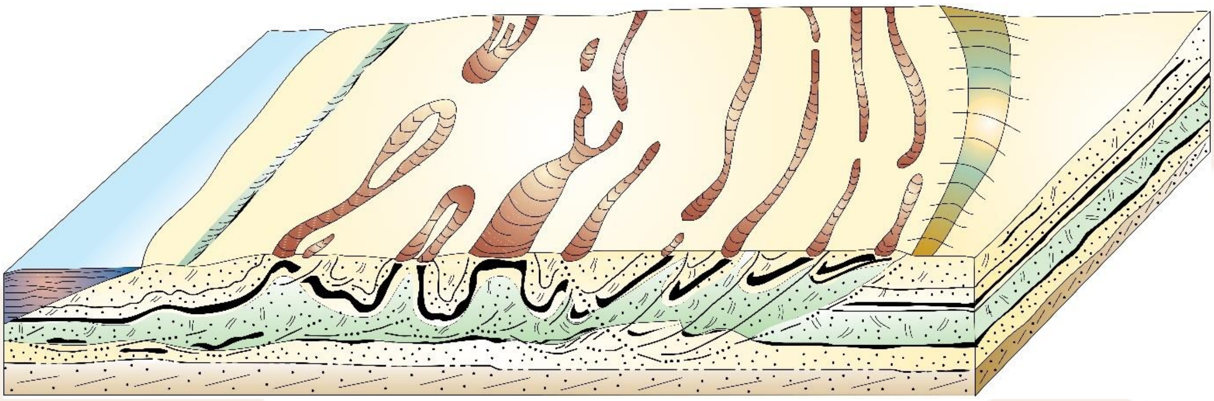

Figure 6: Last step of Muskau Arch formation

Saale period (Drehnte and Warthe) glacial advances level the Muskau Arch. Gieser valleys above the lignite seams are forming at the surface.

2.4. Excavation site

At the end of the 19th century, geologists of the Cottbus Museum of Nature and Environment became aware of the special formation of sand, clay and peat layers and the plant remains and bone fossils found in them in the clay pits of Klinge (12km east of Cottbus). They conducted a geological-paleontological excavation in Eemian (Late Pleistocene) Lake deposits starting in 1985. After some femur remains of a young mammoth had already been found in the Schmidt clay pit in 1894, a largely completely preserved skeleton of a mammoth was discovered in the Grosche clay pit for the first time in Germany in 1903. The find was briefly described in specialist literature in 1908, but then largely fell into oblivion. In 1996, the mammoth was scientifically processed for the first time by the vertebrate paleontologist of the Natural History Museum Berlin, Dr. Karlheinz Fischer.

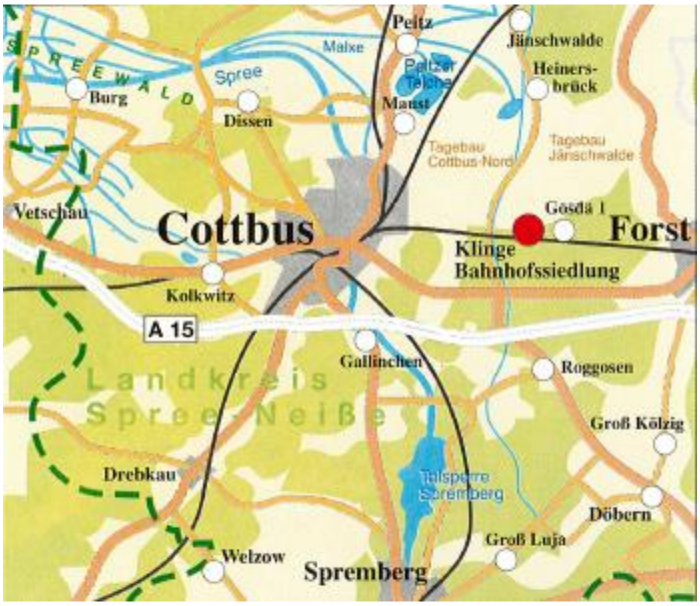

Figure 7: Location of the excavation site

3. Methods

3.1. Climate

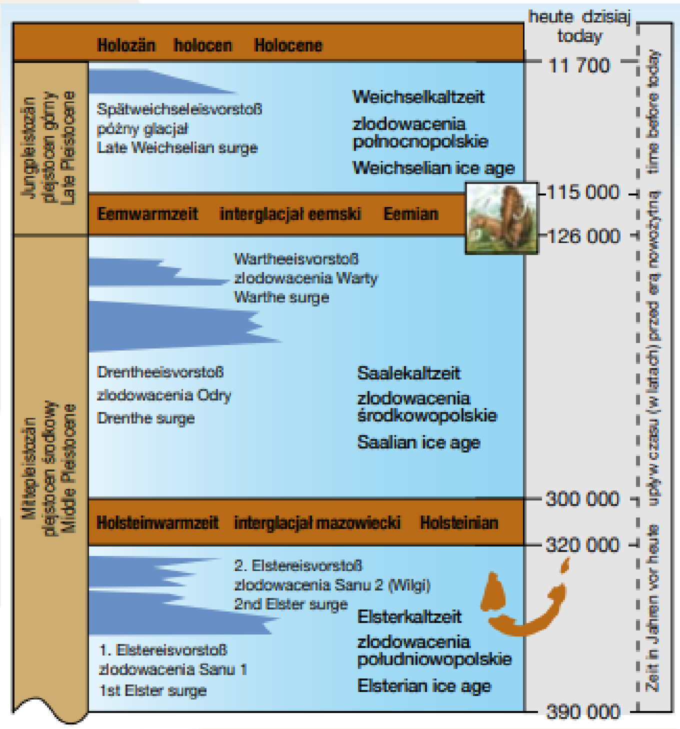

Figure 8: The geological age of the Muskau Arch (Information brochure geopark Muskau Arch)

The Cenozoic Ice Age, which continues to this day, began with the gradual glaciation of the continent of Antarctica at the beginning of the Oligocene (ca 34 million years ago). About 2.7 to 2.4 million years ago, in the vicinity of the Pliocene-Pleistocene boundary, increased ice formation also began in the Arctic. From this time on, repeating cycles (>20 time) of longer cold periods (glacials) alternated with shorter warm periods (interglacials). The region of the Muskau Arch is characterized by a constant alternation of warm and cold periods. During the cold periods huge glaciations developed, during the warm periods all the ice thawed. Within the last 500,000 years there were three major warm and cold periods that affected northern Central Europe:

1) Holocene & Weichselian Ice Age (North Polish cold period)
2) Eemian & Saalian Ice Age (Central Polish Cold Period)
3) Holsteinian & Elsterian Ice Age (Southern Polish Cold Period)

3.2. Climate indicators

There are many indicators that can tell us something about past climates. They are called proxy indicators and are a biological, chemical, or physical signature preserved in the rock, sediment, or ice record that acts like a fingerprint of something in the past.

By extracting and analyzing ice cores from the Antarctic and Greenland ice sheets the composition of the atmosphere at the previous times can be figured out. This is due to bubbles in the ice that enclosed air from up to 800,000 years ago.

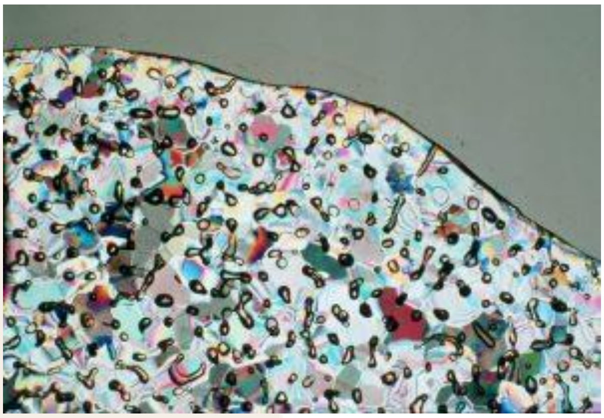

Figure 9: Trapped air in arctic ice

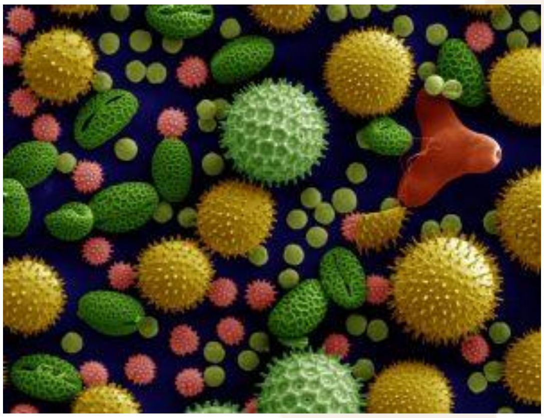

Figure 10: Electronmicroprobe image of pollen from modern vegetation (false-colour image)

Microfossils, like foraminifera, diatoms, and radiolarians can be used as a proxy to interpret past climate record. The different species of microfossils are found in the sediment core's different layers. Microfossil groups are called assemblages. Their composition differs depending on the climatic conditions when they lived. One assemblage consists of species that lived in cooler ocean water, such as in glacial times, and at a different level in the same sediment core, another assemblage consists of species that lived in warmer waters.

Through tree rings we can examine the weather of the passed years. Are the rings thick, it means that there was a lot of rain. Thinner rings indicate a very dry year. Every year, a tree will grow one ring with a light section and a dark section. The rings vary in width. Since some trees are several thousand years old, scientists can use their rings for regional paleoclimatic reconstructions, for example, to reconstruct past temperature, precipitation, vegetation, streamflow, sea-surface temperature, and other climate-dependent conditions. Remnants of dead trees can be used for weather dating back even longer than the living trees.

Pollen, produced by flowering plants, is sometimes preserved in lake sediments that accumulate in layers every year. This way, multiple ancient pollen species, such as spruce, pine and oak, reveal the plants that lived in the area at that moment in time. For example, in the Pacific Northwest, east of the Cascades in a region close to grassland and forest borders, scientists tracked pollen over the last 125,000 years, covering the last two glaciations.

To reconstruct climate change during the Holocene (last 10,000 years), scientists use coral reefs as archives. They tell us about the height of the sea level in the past. Individual coral colonies can even be used to reconstruct the annual cycle of temperature and salinity fluctuations for up to 300 years.

3.3. *Classification of the excavation site: Flora, Fauna, Palynology*

The mammoth of Klinge which was named "Susi" was found in the peat layers of the clay pit Grosche near Klinge in 1903. The skeleton is almost completely preserved. Based on the conservation status of its molars, the animal was the woolly mammoth was estimated to be 45-50 years old. The shape and size of the pelvic bone and the tusks indicate that the mammoth was female. It is said to have a shoulder height of about 2.75m and probably died from sinking and drowning at the edge of the lake. The dead mammoth sank to the bottom of the lake and therefore could not be eaten by predators. Over time, the humidic acids in the bog water turned the bones dark brown and made them durable, which is why they survived in the peat layer. Additional pollen and leaf finds from this layer indicate a climate that was similar to the present one, probably slightly warmer. Remains of wood leaves and pollen of a birch tree were discovered, from which the prevailing temperature could be determined. The average annual temperature was even about 2 °C higher. In the area of Klinge existed several small lakes with fish, water lilies, the associated riparian vegetation, amphibians and reptiles. All this fossil record was found in sediments that are attributed to the Eemian warm period, which prevailed from 128,000 to 115,000 years ago. However, the circumstances of the find at Klinge indicate that the mammoth did not live here under cold period conditions, but settled in a warmer area and was coping very good with this warm period habitat. Conjectures arose that perhaps it was not originally adapted to the cold climate of the tundra and lived in open forest landscapes, near forest edges and floodplains. In addition to the almost completely preserved skeleton, they found bone remains of at least three other mammoths. This find shows that material "climate witnesses" can by far not always be interpreted as clearly as it is often assumed or presented.

3.4. Mammoth profile

Latin name: Mammuthus

Class: Mammals

Size: up to 4m length

Weight: 5 - 15t

Age: 40 - 70 years

Appearance: tusks about 2m long, brown fur

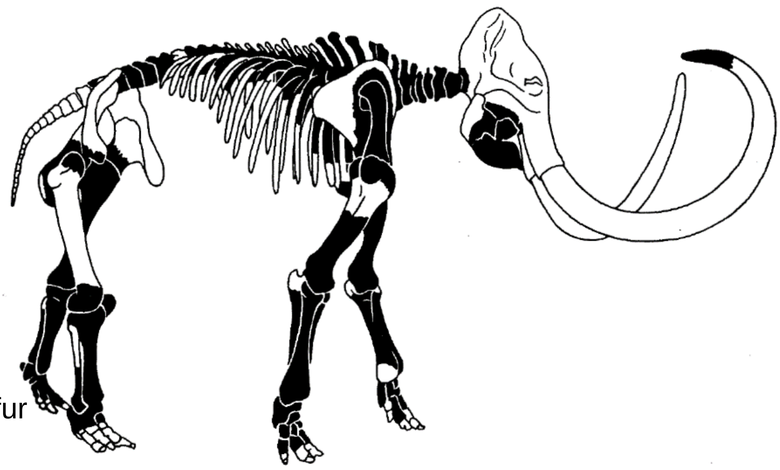

Figure 11: Mammothh skeleton (Fischer 1996)

Sexual dimorphism: Yes

Diet type: Herbivore (herbivorous)

Food: grasses, leaves, plant material

Distribution: North America, Europe, North Asia

original origin: Siberia

Sleep-wake rhythm: diurnal

habitat: cold steppe (tundra)

natural enemies: none

sexual maturity: unknown

Mating season: unknown

Litter size: 1

social behavior: Herd animal

Feeding behavior: huge grinding teeth for grinding green food, chewed teeth were pushed out by new ones

4. Evaluation

4.1. Extinction of the mammoths

Elephants and mammoths evolved at the same time - about four and a half million years ago. But while elephants still exist today, the last mammoths became extinct about four thousand years ago. Why?

Mammoths were the true giants of the Ice Age. Their kinship to elephants cannot be overlooked - even if, with a shoulder height of up to 4.3 meters and a weight of over ten tons, they grew considerably larger than elephants living today. But while the mammoths died out, elephants still exist today. How did this happen?

How mammoths came into being

The dinosaurs were already extinct when - about sixty million years ago in Africa - a group of mammals, called proboscideans, evolved. They had protruding tusks and an elongated nose, the eponymous proboscis. Within this order, various families of species evolved over time, including the elephants. They include the mammoths, but also the three species of elephants still living today, the African elephant, the Asian elephant and the forest elephant.

The prehistoric mammoths still resembled our present-day elephants, but at the same time already had the typical mammoth characteristics: spirally curved tusks and a high-curved head. They did not need a shaggy coat, since warm temperatures still prevailed in their time. But then, about two million years ago, the earth's climate cooled - the Ice Age began. The forests gave way to a steppe landscape, and the leaf-eating prehistoric mammoth found too little food and died out. The grass-eating steppe mammoth followed in its footsteps. With a shoulder height of 4.3 meters and a weight of ten tons, it was the largest mammoth that ever lived.

As the Ice Age progressed, the mammoths became better adapted to the cold. They formed a dense fur and a thick layer of fat. Their ears became smaller, their tails shorter. Grooves of enamel formed on their teeth, allowing them to grind the hard grasses better. Finally, some 750,000 years later, the most famous species emerged at the end of this evolutionary process: the woolly mammoth - today the symbol of the Ice Age. As recently as 25,000 years ago, animals were widespread across the steppes of the entire northern hemisphere.

Why did they become extinct?

Today it is assumed that two main reasons were responsible for the extinction of the mammoths. First, humans hunted mammoths, as we know from finds of spear points among mammoth bones. The huge bones of the mammoths served as building material for huts. On the other hand, climate changes made life difficult for the animals. After the end of the ice age about 13,000 years ago, there was a worldwide rise in temperature. The ice retreated, forests expanded and replaced the steppe. The mammoths, which specialized in grass, were thus deprived of their food source. Only in the colder northern latitudes of Siberia did they still find suitable food. Here the last mammoths died out only about four thousand years ago, as bone finds prove.

The forest elephant, the African elephant and the Asian elephant, on the other hand, are better adapted to a warm climate to this day. This has probably saved the lives of their species. However, humans still pose a threat to them today, as their tusks and valuable ivory are still hunted. And: Increasing settlement is gradually destroying the animals' habitat. In many areas, their populations are therefore severely depleted - and it is to be hoped that they will not one day suffer the same fate as the mammoths.

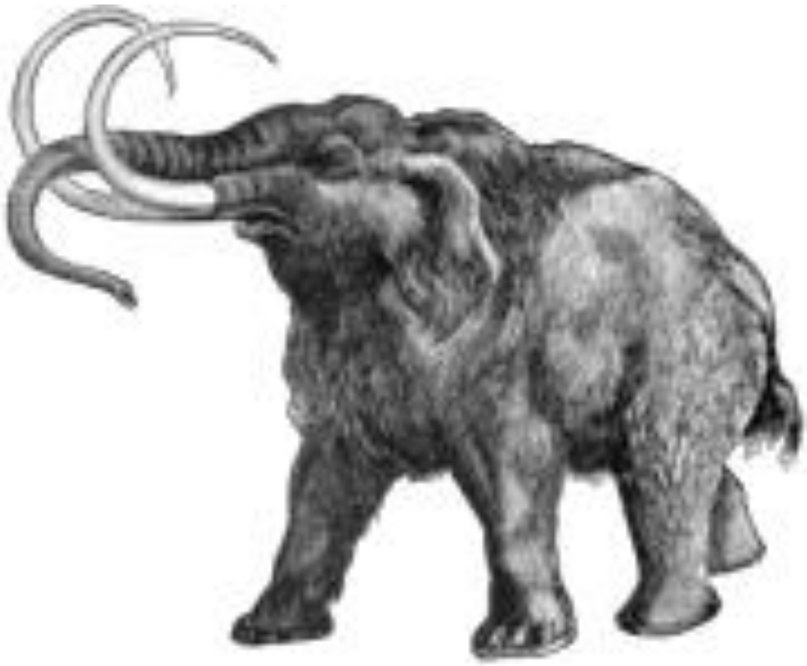

Figure 12: Mammoth (biologie-schule.de)

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IV. International Geopark Camp 2022

Climate changes at the end of the Cretaceous

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Abstract

In our research paper we are concentrating on writing about the climate changes at the end of the Cretaceous. In this period, dwarf dinosaurs lived in the Hațeg Country, so we will take this region as a case study.

We also added important information about the climate, fauna and flora, the asteroid impact, K-T extinction, how the asteroid that killed the dinosaurs was good for bacteria, the rebound of life and how the climate changed after all.

Introduction

This article is written within the framework of the “Geopark Camp” project, developed by the Muskau Arch UNESCO Global Geopark.

The team conducted research using three methods:

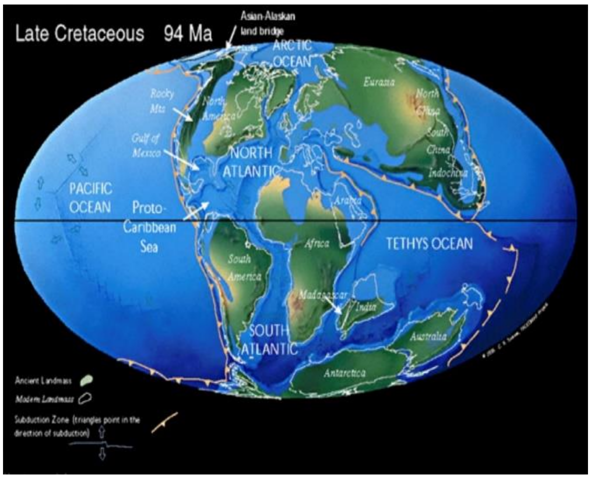
1. Looking for information in the Hateg Country UNESCO Global Geopark’s library and on the internet,
2. Making several fieldtrips on the Geopark’s territory
3. Having live discussions and corresponding with several scientists from the University of Bucharest.

There are three time periods in the Mesozoic era: Triassic, Jurassic, and Cretaceous. Here, we'll concentrate on discussing the Cretaceous period and the climate changes that occurred. Dwarf dinosaurs from Hațeg Island lived at the end of the Cretaceous. Haţeg Country was a tropical island in the Tethys Ocean, around 70 million years ago.

Cretaceous is a division of time that corresponds to the Mesozoic's third and last phase in geological time. Between 145 million years ago and 65 million years ago. The Lower Cretaceous and Upper Cretaceous are the two divisions of this time period. This is also one of the Phanerozoic eon's longest periods.

The beginning of this period is, as many others, quite uncertain. Whether it was a shift in the temperature, the flora and fauna, or the geology, a significant worldwide event determines the start and end of every geological period. Compared to the beginning of this period, the end is more precise. This is because it correlates to one of the geological layers with a high concentration of iridium and that appears to correspond to the fall of an asteroid in what would now be the Yucatan Peninsula and the Gulf of Mexico. (Hansen, 2020)

Figure 3, Late Cretaceous



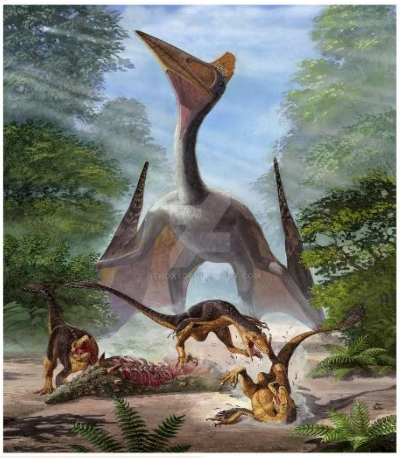


Figure 1, Hateg Country Dinosaurs

Era	Period	Epoch	Age
Cenozoic	Quaternary	Holocene	0.01 Ma
		Pleistocene	1.8 Ma
	Tertiary	Pliocene	5 Ma
		Miocene	24 Ma
		Oligocene	34 Ma
		Eocene	55 Ma
		Paleocene	65 Ma
Mesozoic	Cretaceous	Late	99 Ma
		Early	144 Ma
	Jurassic	Late	159 Ma
		Middle	180 Ma
		Early	206 Ma

Ma: Million years before present

Figure 2, Geological time scale

Dwarf Dinosaurs from Hațeg Island

Dwarf dinosaurs, flying reptiles, and other fascinating animals existed on this island with rich vegetation and active volcanoes.

Despite the fact that everyone now know that these dinosaurs lived between 60 and 70 million years ago due to paleontological discoveries, the exact period was unknown for a long time.

Recent research based on the examination of plant remains found in rocks containing dinosaur fossils indicates that the Haţeg dinosaurs did indeed exist during the Cretaceous period, which saw the extinction of many other types of creatures as well as dinosaurs from other regions of the planet. These creatures may have been among the very last of the dinosaurs that once ruled the continents for more than 150 million years, practically witnessing their demise. (Csiki-Sava, 2021)

Having the dwarf dinosaurs as the central value, the University of Bucharest proposed to the communities of the Hateg Country the creation of a Global Geopark in 2004. From 2005 the Hateg Country UGG is an active member of the Geopark Networks and it continues to tell the story of Earth in this part of the world.

Climate

Haţeg Island had a subtropical climate throughout the Maastrichtian, with average temperatures of 20–25 °C (68–77 °F). Although the island had distinct rainy and dry seasons, the majority of the plant life was tropical in origin. "Dry woodland" conditions are indicated by carbon isotopes. Tropical plants can flourish in a seasonally monsoonal environment as long as they have access to enough water, and the Haţeg environment appears to have been dominated by braided rivers and lakes, which helps to explain the apparent contradiction between the seasonal dry climate and tropical plant species.

Figure 4, Hateg Country Geopark's Logo

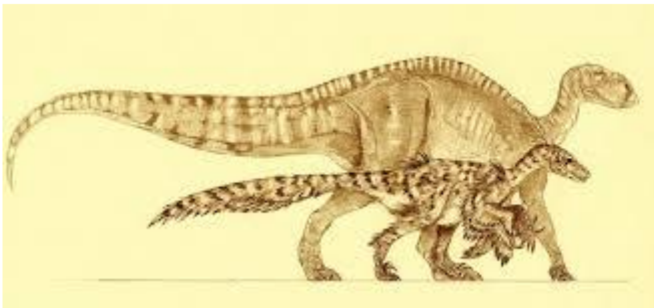


Figure 5, Balaur bondoc and Zalmoxes robustus

Although volcanic deposits predominate in early rock strata, they are lacking in upper layers, indicating that volcanic activity declined over this time. (Csiki-Sava, 2021)

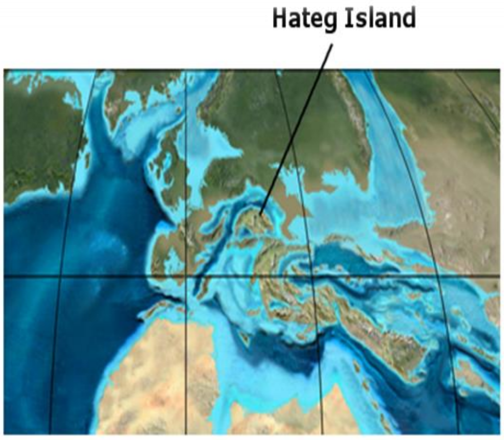


Figure 6, Hateg Island on the globe

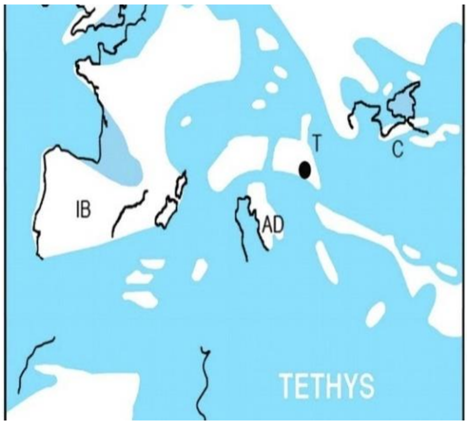


Figure 7, Hateg Island

The Asteroid

One of the three biggest mass extinctions in the previous 500 million years occurred during the Cretaceous-Paleogene boundary, roughly 65.5 million years ago. The extinction catastrophe took place during the Deccan flood basalt volcanism in India and coincided with a significant asteroid impact at Chicxulub, Mexico. Here, we combine data of the worldwide stratigraphy across this boundary to evaluate the mass extinction's potential causes. Notably, along the Cretaceous–Paleogene border, a single deposit that is compositionally connected to the Chicxulub impact is widely distributed. We come to the conclusion that the Chicxulub impact caused the mass extinction because of the temporal agreement between this layer and the beginning of the extinctions, as well as the agreement between ecological patterns in the fossil record and modelled environmental perturbations (such as darkness and cooling). (Encyclopaedia Britannica)

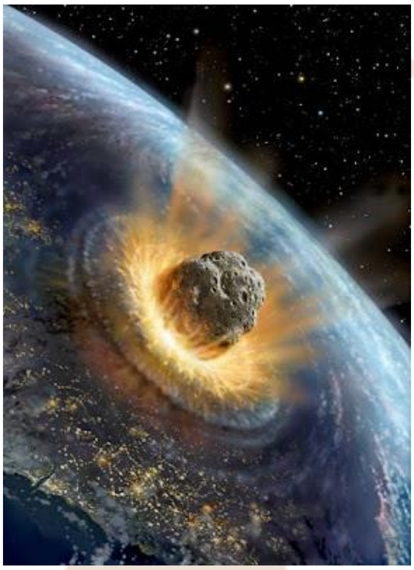


Figure 8 - Chicxulub hitting the Earth

K-T Extinction

K–T extinction, abbreviation of extinction, also called K–Pg extinction or Cretaceous–Paleogene extinction is a global extinction event responsible for eliminating approximately 80 percent of all species of animals at or very close to the boundary between the Cretaceous and Paleogene periods, about 66 million years ago. (Encyclopaedia Britannica)

Consequences:

- ,,The only lines of archosaurs—the group of reptiles that contains the dinosaurs, birds, and crocodilians—that survived the extinction were the lineages that led to modern birds and crocodilians.
- Of the planktonic marine flora and fauna, only about 13 percent of the coccolithophore and planktonic foraminiferal genera remained alive.
- Among free-swimming molluscs, the ammonoids and belemnoids became extinct.
- Among other marine invertebrates, the larger foraminifers (orbitoids) died out, and the hermatypic corals were reduced to about one-fifth of their genera.
- Rudist bivalves also disappeared, as did bivalves with a reclining (or partially buried) life habit, such as Exogyra and Gryphaea.
- he stratigraphically important inoceramids also died out.'' (Encyclopaedia Britannica)

Figure 9, Ammonite cluster

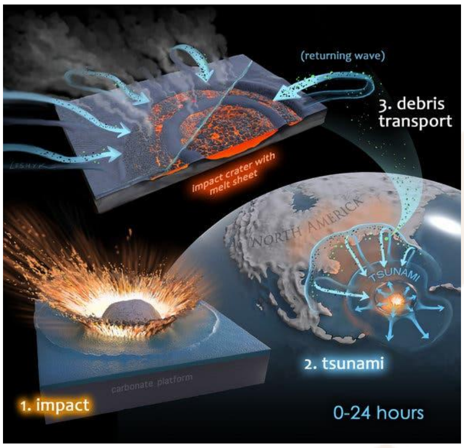


Figure 10, 24 hours of Chicxulub

Chicxulub and Bacteria

The space rock left a crater nearly the Gulf of Mexico. Not a single creatures survived. Cyanobacteria (blue-green algae) moved into the crater a few years after the impact.
When the scientist's team saw those preserved fats in the core near the time of the impact, they knew cyanobacteria must have been present. Also, the fats were deposited a top a layer of fossilized plants that were washed into the crater by the tsunami that followed.
The bacteria began to populate the crater after the tsunami hit, but before the atmosphere cleared and the sun's light had fully returned. (Hall, 2020)

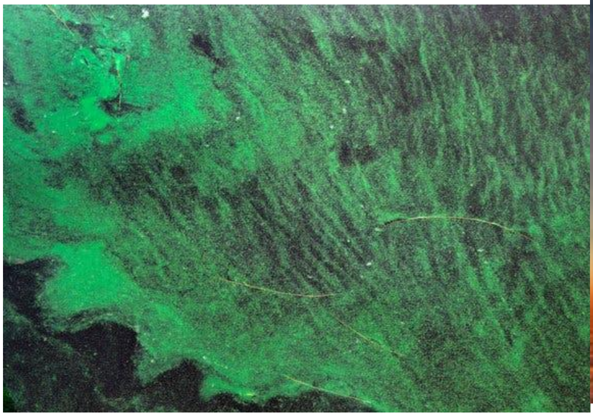


Figure 11, Blue-green algae

Figure 12, Chicxulub impact

Rebound of life

A few months of near total darkness and up to 2 years of twilight occurred because of dust and aerosols in the stratosphere. The dust and aerosols caused major global climate change, called an impact winter, resulting in the collapse of food webs and the well-documented simultaneous extinction of organisms from both land and sea.

With less sunlight for photosynthesis, the number and size of photosynthetic microfossils sinking through the water column decreased. It takes time for life to return after such a catastrophic event.

How do we define recovery of life?

- “Productivity is a measure of energy produced and consumed, even if just by a few survivor species or even a single extremophile population.
- The productivity of marine ecosystems in the North Atlantic took about 300,000 years to be restored.
- In the immediate area of the crater, however, life returned more quickly. Within the crater itself, marine organisms rebounded in less than 6 years.
- Animals with low weights (less than 25 kg, or 55 lbs) and low metabolic rates survived the starvation suffered by larger organisms.” (Lowery)

Conclusion

When the asteroid hit our planet, the climate suffered. Because of the impact, the crust changed and a massive dust cloud enveloped Terra and the rain contained acid. After this, some species disappeared and some survived building up a strong defence mechanism. In the Gulf of Mexico, the blue-green algae started to live after just a few years of the impact. This is a perfect example of rebound of life. The climate change was very good for the next generations of species.

Life always finds a way to come back in extreme and cataclysmic conditions.

Figure credits

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IV. International Geopark Camp 2022

Climate change recorded in the landscape – inland dunes

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Introduction:

Geology is a difficult area of science to understand for an average person. However our project group had a possibility to change this stereotype and deepen the knowledge about geology of the Muskau Arch UNESCO Global Geoparks. Our school teacher encouraged us to take part in the project and to broaden our way of thinking about sustainable development and climate changes. We have been studying geography for 2 years on an advanced level at High school. However, only after working on this publication during the project we realised that in this field there is for a lot to learn, to explore and to discover in the case of geoparks, especially the Muskau Arch as the cross – border UNESCO Global Geopark.

Figure 13: The workshop group (the author: Hanna Słomka)

Have you ever been to a geopark? A designated area with geological sites and landscapes of global significance. It hides stories to be discovered and shows us the past with the witnesses of the climate change. Knowing the topographical background we can understand why a landscape looks the way it does today.

There are 177 UNESCO Global Geoparks which focus on sustainable development, preserving heritage which then would be available for the visitors. Moreover, they promote the region, educate and cooperate internationally. Geoparks perform for better future of the planet adopting the 2030 Agenda for Sustainable Development and concern with global challenges, such as climate change and exhaustion of raw materials.

Geoparks are more than just pretty landscapes. They have many goals to be fulfilled such as,to support nature and make it accessible to all of us – nature lovers. If you are one of them you should visit the UNESCO Global Geopark Muskauer Faltenbogen / Łuk Mużakowa. It is a cross-border geopark located in Brandenburg, Saxony and the Polish Lubusz region. In 2011 Muskauer Faltenbogen / Łuk Mużakowa Geopark joined the European Geoparks Network (EGN) and the Global Geoparks Network (GGN). In 2015 it was awarded the "UNESCO Global Geopark" status. If you look at the geopark from the bird's perspective it resembles a big horseshoe.

Figure 14: The Muskau Arch Geopark on the Polish side, the workshop with dr. J.Koźma (the author: Agata Słomka)

The arch you can see was formed during the Elsterian ice age 340,000 years ago by the Muskau glacier. It deformed the underlying sediments to a depth up to 300m and piled up masses of earth in front of it, that's how the pushend-moraine, called Muskau Arch, was created. Thanks to the Muskau glacier many resources were brought up to the surface of the earth. Because of that, industries dealing with extractions and processing of natural resources benefited for 130 years! Lignite, glass sand, alum and clay are some of the natural resources that were mined in that period.

"It used to be a coal mine, but now it is a mine of knowledge!" ~ Maja Saleniuk

During our two discovery tours we explored the geopark and learned about its secrets. On the first tour, we set of at the Cultural Center in Łęknica in the direction of a dune at the Big Lake, passing the dense forest area, beautiful landscapes with all the richness of forms: water bodies, dry valleys, tarns, erratics springs and much more.

Figure 15: The Muskau Arch Geopark on the Polish side, the workshop with dr. J.Koźma (the author: Agata Słomka)

The bike ride was a challenge – we had our ups and downs. It turned out that we were actually riding on and across inland dunes, the subject of our research. The first step of our study was to recognize the particular dune, uncover it with a spade and study the intersection. Our mentor – doctor Jacek Koźma, the geologist from the Polish Geological Institute in Wrocław, taught us the structure of the dune and how it was created. We also analyzed the sand samples collected from different heights of the dune.

Figure 16: The colorful lake at the Babina mine (the author: Maja Saleniuk)

On the second discovery tour to the former Babina coal mine, we came across very interesting mine forms of landscapes. The picturesque views, colorful iron springs and the 120 steps tower at the Africa Lake left us speechless but also yearning for more.

Figure 17: The post - mine lake (the author: Giulia Pisani)

The aim of our study were the inland dunes that are the best example of the climate change in the past. The rocks and the landscape which keep the secret of the accomplished period in geology.

Figure 18: The iron - rich spring (the author: Agata Słomka)

Dunes

A lot of people believe that dunes exist only in sea areas near beaches, but it's far from the truth. The Muskau Arch breaks this rule. In the east part of the geopark, across the forest you can also discover dunes that look exactly like the ones from the sea postcards. They are called inland dunes. Hills in the forest where an average person wouldn't recognise this unique form of post-glacial land form.

Figure 19: A photo of an inland dune (sources of the Muskau Geopark)

The parabolic dunes that we observe in the Muskau Arch are full of surprises. The average height of over 10m and several hundred meters in length. Also these dunes are geologically rather young. They were formed at the end of the last Ice Age.

What is a dune? A dune is a land form created by wind and its activity. They occur both in dry and humid climate. Dunes are built out of sand piled up upward by the wind (aeolian transport). The dunes are formed when the transported sand meets a humid place or weak ground vegetation (grass, bushes) and sticks to the ground. When the sand reaches the crest of the dune the wind looses its transporting power and the sand is settled down on the bottom of the dune's outer edge increasing its volume.

The universal structure of a dune:

- windward slope (a zone where sand is blown upwards by dominant wind and transported to the crest of the dune)
- dune ridge (the highest point) that can occur in many forms wide, flat or narrow
- leeward slope - the place of movement and deposition of sand, because of this process the dune can change its shape, size and width.

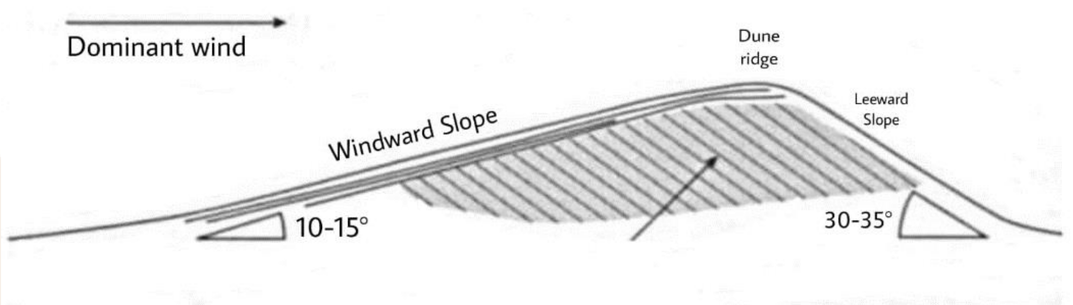

Figure 20: A universal structure of a dune (Translated from Geomorfologia, Piotr Migoń, Wydawnictwo PWN)

Aeolian processes and winds.

Aeolian transport is a transport of minerals, stones, grains, smaller rocks, gravel moved with the power of the wind. Effectiveness of this process depends on the force of the wind and the size of the carried material. Smaller and lighter grains are carried forward higher and further. On the other hand, the heavier ones are rolling on the surface.

During the transport, the stone material is lifted by the wind's power and while falling onto the ground they crash to one another, break, split into smaller parts. Thanks to this aeolian process the rock particles is sorted out and polished.

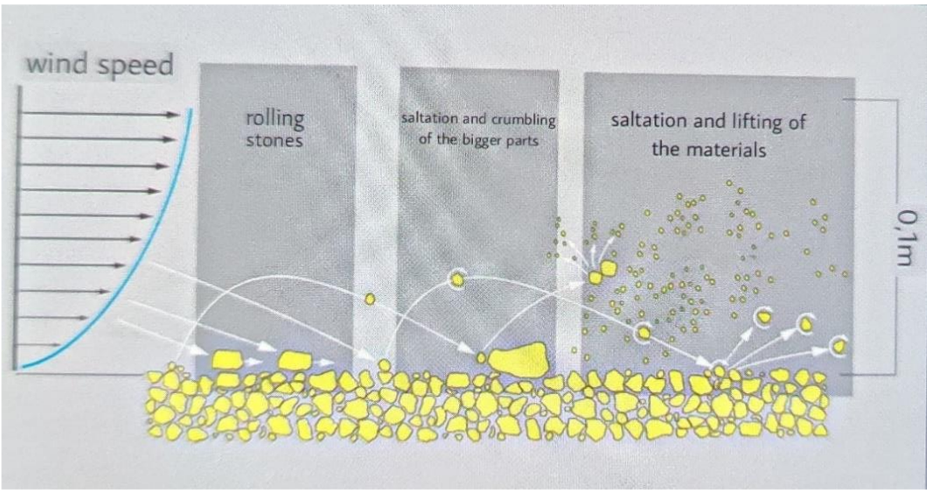

Figure 21: The aeolian transport (The information chart from the geopark path)

Dunes in the Muskau Arch

The Muskau Arch Geopark on the Polish-German border covers the area of about 600 km^2 and the dunes appear on both sides. Our group took part in two discovery tours and made an interesting research on two of them: „The dune at the Big lake" and Przewoźniki dunes at Skroda valley.

Figure 22: The workshop group at the Big Lake (Julia Drabek)

Discovery tour 1: Tuplice, Lubuskie, Poland

In May, 2022 our group of Polish students together with dr. Jacek Koźma (Polish Geological Institute) and Ewa Brauer the geoparks employee for Education for Sustainable Development, explored a dune nearby the Big Lake. The aim of the tour was to learn, collect samples, and analyse the evidence of the climate changes. We learnt not only about the dune's construction but also how and when it was created. We took samples of the sand, watched it under the lens and analised its shape, weight, size and limpidity.

Figure 23: Dune at the Big Lake (The geoturistic map of the Geopark)

„The dune at the Big Lake" is a place where we focused our attention most. With its parabolic form and easy access it became a perfect example of a parabolic inland dune to make a research on.

The dunes are the youngest geological formations in this landscape and were formed at the beginning of the holocene period (ap. 10 000 years ago or later). At the time of the formation of these dunes, there were changes in climate conditions that resulted in unidirectional winds. These winds slowly but successfully created the formation of dune formations. The wind that participated in the formation of „the dune at the Big Lake" had a west direction, which explains the shape and direction of the outer edge. The dune formation occured in the area located in the foreland or within river valleys when there was significant amount of material susceptible to be blown away.

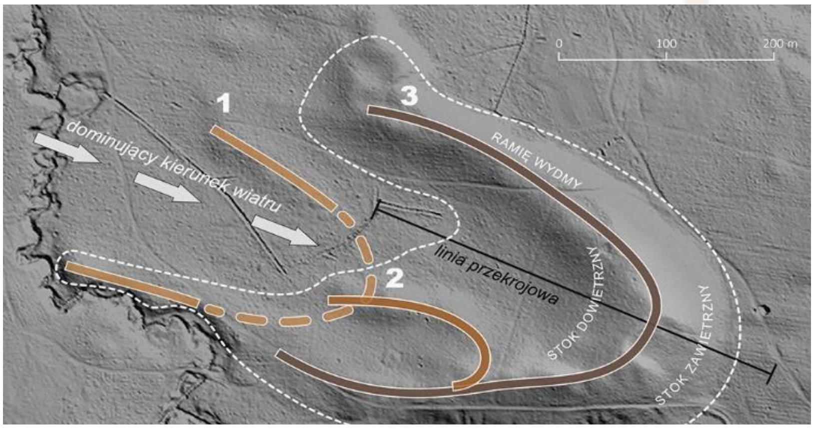

Figure 24: The dune at the Big Lake - digital terraine model of a dune (the information chart from the geopark path)

In the 20th century the dune was still visible, but it began to overgrow with forest material, making it hard to observe that we are dealing with a dune.

Below we present a photo of the excavation of this dune.

Figure 25: The process of uncovering the Dune at the Big Lake (the author: Giulia Pisani)

Figure 26: The observation of sand at the Big Lake dune (the author: Inga Dybek)

This particular dune has a regular parabolic shape. It consists of two arms (with a span of about 340m which are directed in the direction of the prevailing wind direction), the perimeter of the dune hill is about 1.8km. The entire dune covers an area of 13 ha.

In its center there is a deflation niche which is the wettest part of the dune. Sand was blown from this place. This is evidenced by the view from the top of the dune. When we stood in the front zone, we observed that the vegetation is poor and the soil is very dry. But the vegetation on the deflation niche within the range of our eyes was extremely luxuriant and lively. The soil horizons mark the period of stabilization of the dune and the periodic disappearance of aeolian processes.

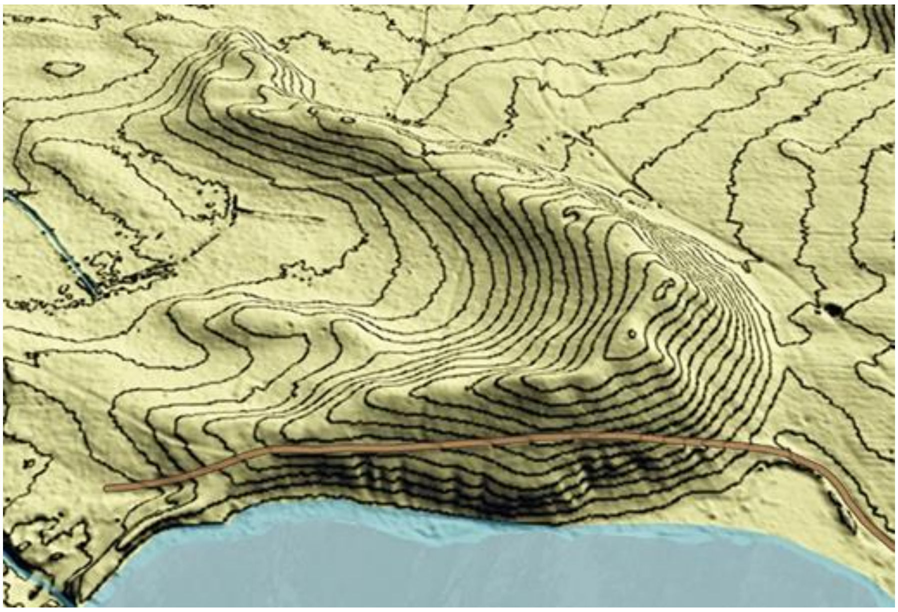

Figure 27: The dune at the Big Lake-3D model (The information chart from the geopark path)

Figure 28: The top of the dune covered with dense forest (the author Hanna Słomka)

Sand was the most important material that we investigated precisely.

Features we observed during the dune exploration:

- -fine-grained and medium-grained(size of the sand)
- -fluvio-glacial sands, were carried by meltwater flows to its foreland(type of sand)
- -transparent, matte, shiny, rounded and rimmed(due to aeolian forces)
- -90% quartz in this sands, yellow (from iron)

Figure 29: The sample of sand under a lens (the author: Maja Saleniuk)

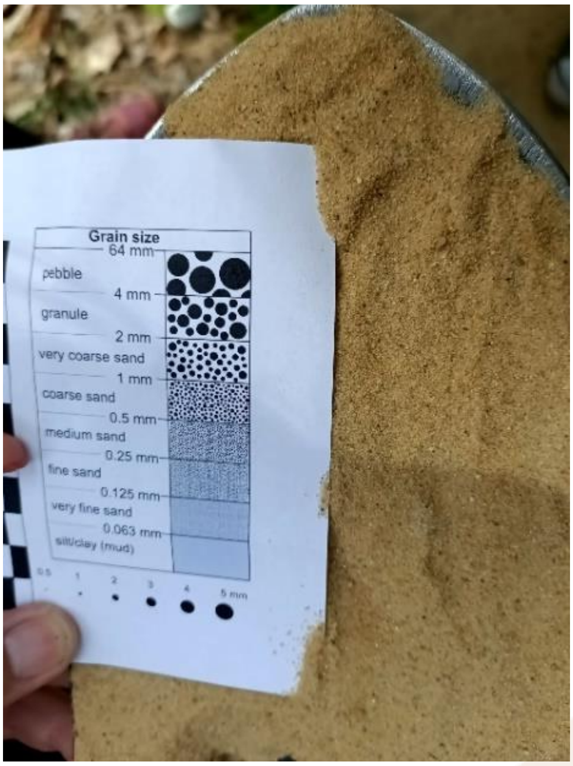

Figure 30: The analysis of the size of sand grains (the author Inga Dybek)

Discovery tour 2: Przewoźniki, Skroda Valley, Lubuskie

In June 2022 the second part of the research of dunes took place. Dr. Jacek Koźma. The geologist introduced us another example of an inland dune in the Muskau Arch Geopark. We set of at the entrance of the Babina mine in the direction to Przewoźniki. On the way, we could admire antropogenic lake districts and mineral springs.

During the exploration of this dune, we learned what aeolian processes are and what role they had in the formation of dunes in the Muskauer Arch Geopark. During the exploration our goal was to of find ventifacts which in our opinion, are the most interesting examples of aeolian processes.

It is a rock form against which other small elements raised by the wind blow, therefore in this process there was constant cutting and polishing the rock's sides. This action created a peculiar granular form, which consists of smooth walls with sharp ridges (peaks).

Figure 31: The observation of ventifacts (B.Salamon)

Figure 32: The ventifact found at the Skroda valley (author: Maja Saleniuk)

Figure 33: Ventifacts from dune at Skroda Valley (the author: Blanka Salamon)

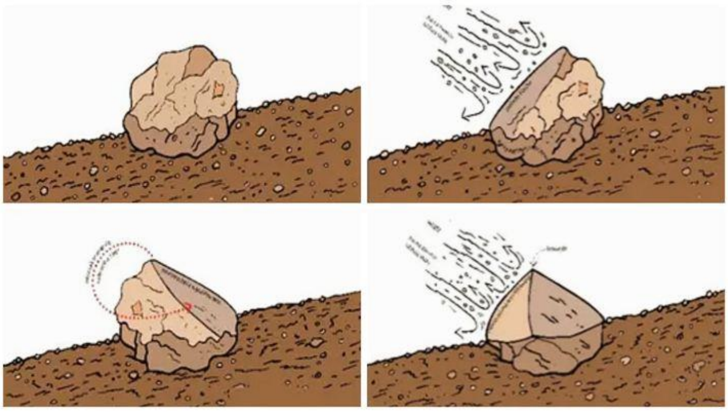

Figure 34: Process of creating ventifacts (Geopark Muskau Arch)

a) A rock from a glacier
b) A rock stuck to frozen ground. The blow of the wind on one side of the rock
c) c) Defrosted ground changing the place of the rock.
d) d) A rock stuck again to frozen ground with the wind *blowing from one side and polishing the rock with the wind's* inside material

Results of the approach to exploration of the Muskau Arch dunes

The results of our case study were not obvious. As for aeolian winds, we did not expect them to have such influence on changes in the landscape of the Muskau Arch. Moreover, we discovered that the features of sand were the same in both of the dunes despite their difference in location. Their parabolic construction and consequences of it also turned out to be similar: a horseshoe shaped arch, deflation niche and overgrowth of forest material. The most visible difference was the number of ventifacts. On the dune at the Skroda valley there we could find more various sizes and shapes of them.

Figure 35: The dune in the Skroda valley (the author: Agata Słomka)

Summary and the outlook

The research on dunes resulted in intensive cooperation with dr Jacek Koźma, Ewa Brauer from the Muskau Arch Geopark and the youth from the IV International Geopark Camp.

The participants of the project gained invaluable knowledge and skills. We understood the processes of the climate changes and abilities to observe the global warming effects. Moreover, we learned to recognize characteristic structures created after the Ice Age. Last but not least , we got the awareness of nature objects that are visual witnesses of the climate changes in our environment.

The area of the Muskau Arch with its dunes and all its diversity and geosites worth of protection, appears to be a perfect destination not only for the geology enthusiasts but also for an average visitor who would like to feel the changes of the past personally. The region of the geopark is an ideal place for school trips with the educational aims concerning nature protection, climate change, understanding the processes on the earth and sustainable development. The landscape of the arch may be explored on foot or by bike (as we did) along a well-developed network of paths which take you to the world of amazing iron- rich lakes of different colours, beautiful valleys which turned out to be the dunes, biodiversity of species and "the cherry on the top of the cake"- the viewpoints over the entire area of the arch.

Apart from that, as a UNESCO World Heritage Site, the Muskau Arch is the only unique transnational Geopark in Europe and one of only four worldwide.

While we were exploring the dunes there appeared a lot of questions for further studies. The most valuable ones are: What will happen with the dunes in the future? Will they survive the changes they experience at present? Will people respect the knowledge hidden inside the dunes? These questions are still to answer and provoke us to further research.

Taking all the studies that we have done so far into consideration, the Muskau Arch tour is a must for every person aware of the role of humanity in preservation the world's heritage and the dunes are just the tip of the iceberg to explore.

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Participants feedback:

Agata: Every time I join an international action, I am never disappointed and so was this time. Workshops like these make me believe that we will manage the future, that the youth will finally understand that this is our world. I am proud of my students that they took the challenge and wanted to be a part of an important issue which is Geology and sustainable future “One small project for a student is a giant leap for a mankind and our nature”.

Inga: Thanks to the project I got to know some awesome people from different countries. We had so much fun working and learning together. My memories from here made me realize that international projects aren’t only for us - young people - but also for the sake of sharing good practice and knowledge.

Maja: Before the project, I thought geology was not a field that would particularly interest me for a longer time. Geology is a bottomless subject that is hard to explore on its own. Thanks to my work on the topic of dunes, I discovered how fascinating they are and that tying the future to the topic of geology is a good idea.

Blanka: I understood that our environment has always been changing and it will change no matter what. However, we have a lot to do, we must save natural resources and protect natural heritage for next generations. It is not an easy task. I believe that the key is in Youth.

Hanna: Knowing more about importance of climate changes was always my priority. During this project I had an opportunity to see these processes with my eyes. That was a real life lesson. I had also a lot of fun during the international camp week.

Julia: Before joining the project I was not aware that dunes may appear in thick forests. The knowledge I gained during exploration of the geopark let me understood the importance of being responsible for global issues such as climate change. A single action may have a worldwide impact.

Giulia : Before taking part in this project, I had no particular interest in geology nor had I heard much about it. However, thanks to this project, I learnt about its importance and how different processes create the physical world we live in. I also realized how large of an impact climate and human activities have on the Earth's landforms.