Palynology

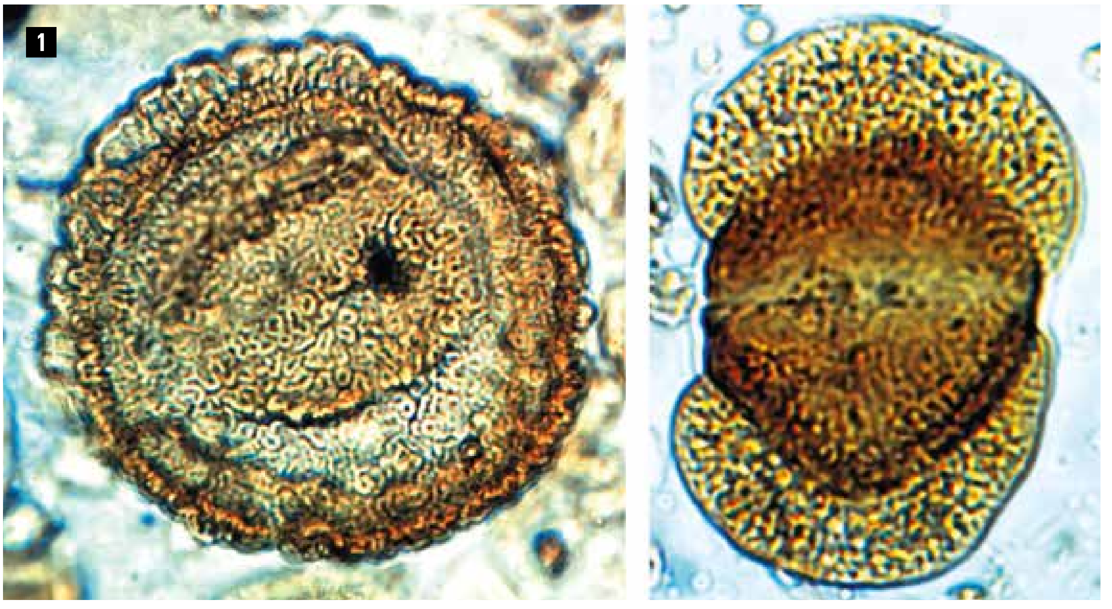

Fig. 1:
Pollen grains from the middle Miocene, contained in lignite

Rocky record of hot and cold

The pace of climate change observed since the beginning of the industrial era has prompted scientists to seriously consider whether human activity is to blame for global warming. On the geological timescale, however, climate change is certainly nothing new or exceptional – as is clear when one looks at the record of plant and animal fossils.

Dr. Barbara Słodkowska

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A record of the climate in ancient geological epochs is preserved in sedimentary rocks. Salts, gypsums, coal deposits, and glacial formations also serve as indications of the conditions that prevailed back when those deposits were formed. The set of plant and animal remains that are frequently preserved in such rocks frequently supply detailed information about climate conditions, through comparison with the climate requirements of modern ecosystems.

Warming

Sediments formed during the Paleogene and Neogene can be used to analyze the significant climate changes that took place from 66 million down to 2.6 million years ago. These phenomena were of global scale and were mainly due to geotectonic processes: continental drift, earthquakes, volcanic eruptions. Such events caused the methane hydrates accumulated on the ocean floors to be released into the atmosphere, reinforcing the greenhouse effect. The concentrations

Dr. Barbara Słodkowska, a researcher at the Polish Geological Institute engaged in the Climate and the Environment Changes Program, has done palynological research on Paleogene and Neogene deposits (including lignite) which are utilized to establish the stratigraphy of sediments, the reconstruction of paleoflora, and also paleoclimatic reconstructions. Her interests also include analyzing plant remains found in Baltic amber.

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of greenhouse gasses – water vapor, methane, and carbon dioxide – in the early Paleogene were ten times higher than at present, and the prevailing climate was tropical and subtropical. Climactic zones were not prominently marked. These global data were recovered from the record of changes in the isotope ratio $\delta^{18}O$ preserved in the shells of benthic Foraminifera – single-cell organisms living in the sea. The greenhouse effect phenomenon is evident in fossils from Eocene deposits at high geographical latitudes (the subpolar regions), which preserve the remains of highly thermophilic plants (tropical and subtropical), both macro- and microflora.

The subsequent drop in greenhouse gasses was partly caused by geotectonic factors, among them being the fact that the Artic Sea was separated by a land barrier from the waters of the world ocean in the middle Eocene. Rivers flowing in from the surrounding landmass caused the desalinization of the Arctic basin waters, leading them to become inhabited by water fern from the Azolla genus, which captured the excess atmospheric CO_2. Its significant drop, from 3500 to 650 ppm, contributed to a reducing in surface water temperature, from 13°C to -2°C. The next factor leading to cooling was the separation of the South American continent from Antarctica, the emergence of the Drake Passage, and the formation of the cold Antarctic Circumpolar Current, which formed a thermal barrier for warm air masses and marine currents from the north. In the northern hemisphere, as well, seasonal drifting icebergs began to appear with increasing frequency, which led to further cooling. The transition from the late Eocene and early Oligocene saw the end of the greenhouse epoch without ice cover.

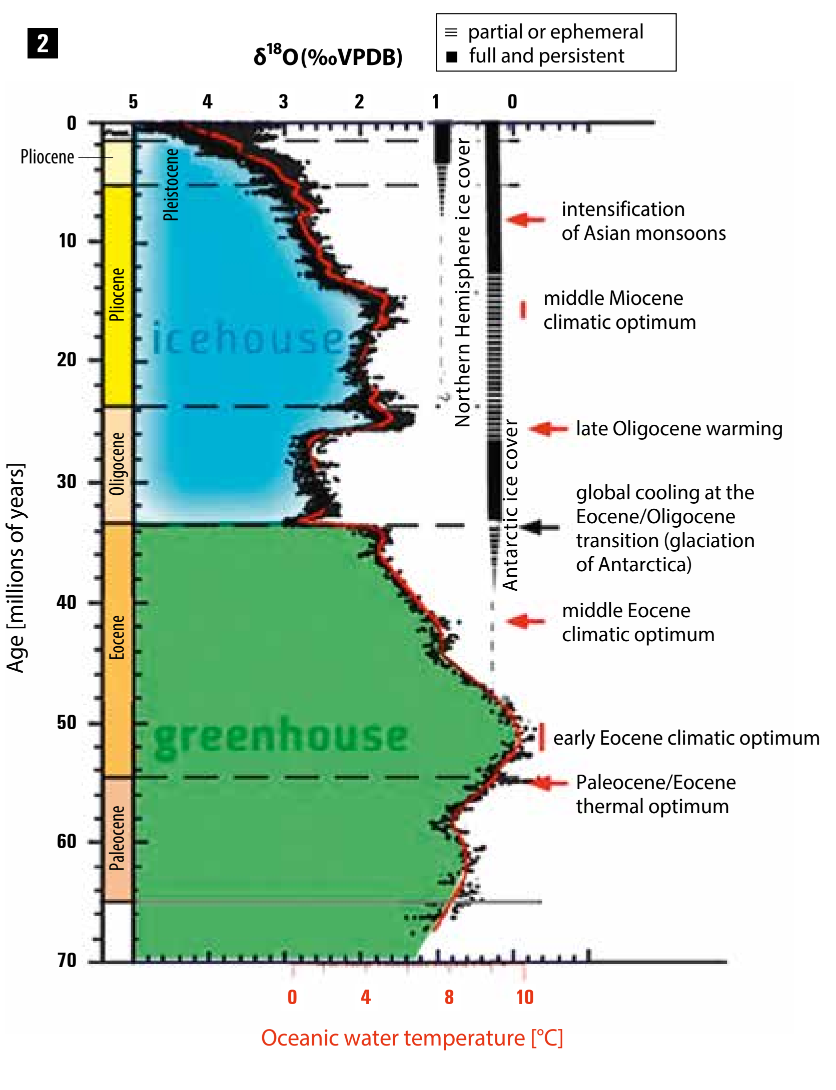

Fig. 2: Global changes in the ratio of oxygen isotopes ($\delta^{18}O$) over the past 66 million years, as recorded by the shells of benthic Foraminifera (based on the work of Zachos et al. 2001, 2008, with modifications), and the correlated climate changes

Cooling

The quickest to react to these climate changes were the plants, changing their composition and character. For instance, plants that shed their leaves in the winter began to appear. And although thermophilic plants continued to dominate, tropical species occurred sporadically. An icehouse climate came to prevail, with initially ephemeral but later permanent glaciers.

Climate fluctuations are also seen in the late Paleogene and Neogene, but they are of smaller amplitude than in the early Paleogene. The plant life at that time was something like what we can see today in the subtropical and warm temperate zones.

During the Miocene, quite stable climactic conditions prevailed in the Northern Hemisphere, particularly in the region of the European Upland, for about 22 million years. The dampness and temperature were conducive to the formation of extensive swamps and peat bogs, which next gave rise to thick deposits of lignite, interlayered with episodes when coal did not form. This variability was caused by geodynamic factors, including subsidence, compaction, and epeirogenic movements. The Miocene coal-forming cycles are well documented in the profiles of western Poland, where all the main seams of lignite have been preserved. Assemblages of marshy forests, peat bogs, and reed beds show similar composition of microflora remains during the formation of the successive coal deposits. Differences in the composition of sporomorphs (fossil pollen grains and spores) contained in the individual layers are mainly found in the assemblage of mesophilous forest surrounding marshy basins and peat bogs, and it is they that register ongoing climate changes. Each successive coal seam contains decreasing quantities of spores and pollen grains from highly thermophilic plants. However, the climate was still conducive to lush vegetation, crucial for the creation of significant quantities of peat-forming plant material. The rise of the Carpathian arch gave rise to an orographic barrier to the influx of warm and damp air masses from the south.

In the late Miocene, the climate became dry enough that extensive swamps ceased to exist. The arid climate triggered the expansion of grasses, which contributed to lower quantities of atmospheric CO_2. Geotectonic reconfiguration also had an impact on the circulation of the oceanic currents, shutting down the circum-equatorial corridor by through which warm-water currents flowed. The gradual drying and cooling led to a relaxation of the forest cover and the dominance of steppe assemblages at the transition from the Miocene to the Pliocene. The reduction in forested surface, the exposure of brighter ground, and the appearance of ice cover caused solar rays to be reflected away from the Earth's surface. This led to global cooling (the *albedo* effect). The Pliocene was significantly cooler, and extremely unfavorable climactic conditions prevailed during the Pleistocene glaciations (around 1 million to 10,000 years ago). Other important factors driving climate change included orbital phenomena, such as cyclical changes in the Earth's orbit and axial precession.

Moderation

When comparing these climactic phenomena to those of modern times, one should bear in mind that we are currently observing an period of time that is extremely short on the geological scale. The around 150 years of meteorological measurements that have been taken since the beginning of the industrial age are just "the blink of an eye" compared to the changes that have taken place in the Earth's geological past since it first formed, in other words over 4.6 billion years. As such, it is hard to draw global conclusions on their basis.

Excessive emissions of greenhouse gasses into the environment **should be controlled.**

Forecasts present future climate change as very significant, having a negative impact on all fields of modern life. This is only partly true, because the extreme weather phenomena we are currently experiencing are frequently confused with the notion of global warming.

Excessive emissions of greenhouse gasses into the environment should not be trivialized. They should be monitored and controlled. However, it should not be forgotten that the human factor can only reinforce trends of climate change, whereas they can be caused only by geotectonic and orbital factors.

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Further reading:

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