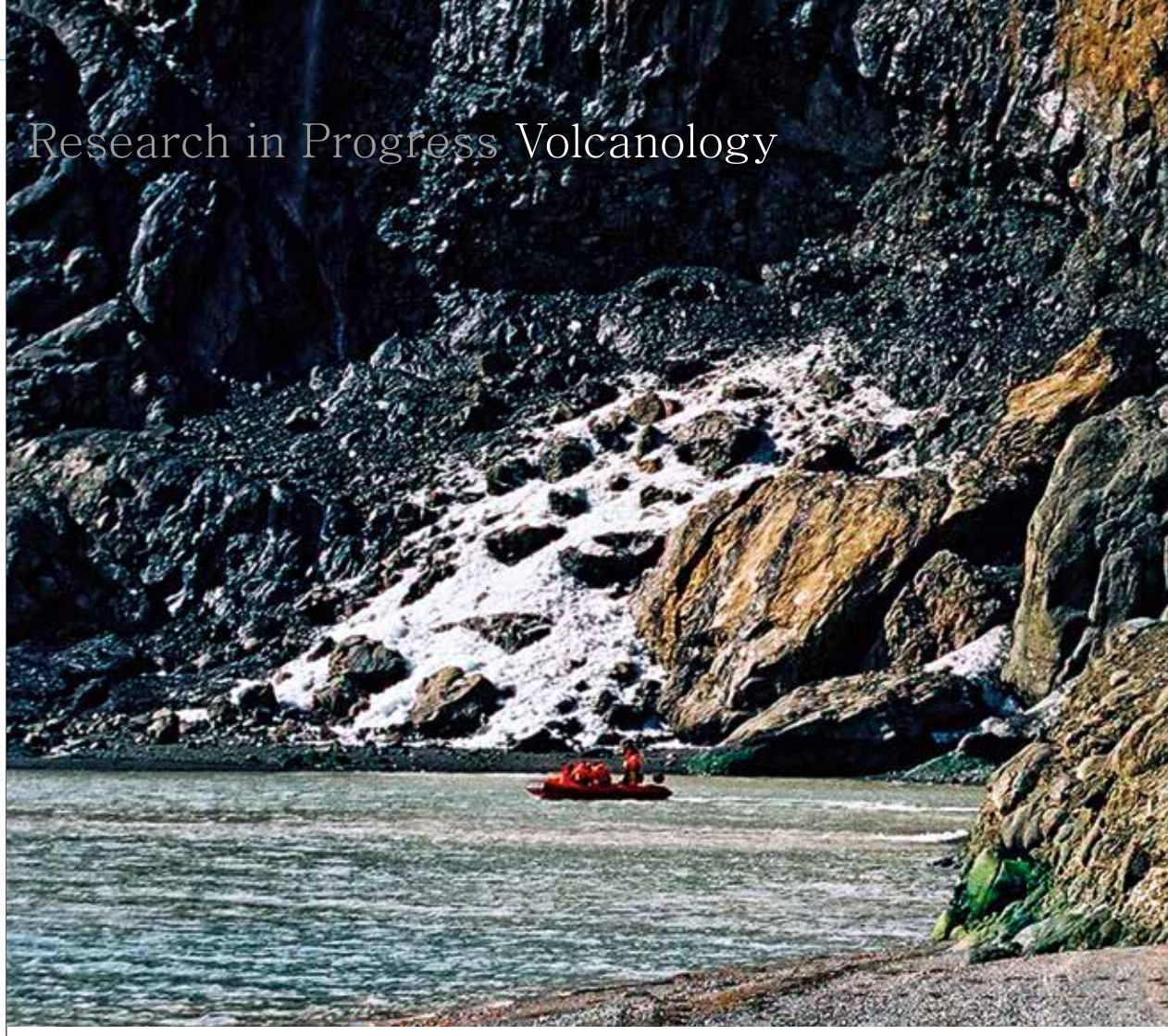

Ancient moraine (tillite) from Hervé Cove on King George Island. The age of the volcanic rocks surrounding the boulders shown here indicates that the moraine was formed almost 49 million years ago.

Ice From Dust

Antarctica is home to numerous relatively young volcanoes from the Cenozoic era. According to one hypothesis, their activity was one of the factors driving the continent's glaciation.

Prof. Jerzy Nawrocki

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Scientists believe that in the early stages of the development of the cryosphere in the Antarctic, the continent was isolated by the Antarctic circumpolar current, formed by the opening of the Drake Passage around 41 million years ago. However, this neat theory has been challenged by the discovery made by Polish researchers from Prof. Birkenmajer's team working on King George Island in the South Shetland Islands, who found traces of an alpine glacier in the form of an ancient moraine (tillite) dated to be 48.8 million years old. The moraine was formed soon after the equable climate of the Early Eocene, when the greenhouse era rich in atmospheric carbon dioxide came to an end. So what was the region like during the transition into the current Icehouse Epoch?

AUTHOR'S ARCHIVES

There is no doubt today that major emissions of volcanic dust can contribute to the cooling of global temperatures. The question of the influence of volcanism on the Antarctic climate is a priority research subject developed by scientific circles for the Scientific Committee for Antarctic Research, formulated in *Antarctic Science* as "How does volcanism affect the evolution of the Antarctic lithosphere, ice sheet dynamics, and global climate?"

Resistance of grains

Volcanic eruptions of different intensities took place all over the globe during the Cenozoic and earlier eras. In Western Antarctica, they left behind what is known as the Cenozoic volcanic province. Processes linked with the subduction of the Phoenix tectonic plate under the Antarctic plate contributed to volcanic activity here, including the formation of volcanic island bows. The internal bow of the Antarctic peninsula was mainly formed during the Mesozoic, while the external bows of many nearby islands were mainly formed by younger, Cenozoic subduction processes. Volcanic rocks of the Cenozoic beyond the South Shetlands, which include King George Island, and the nearby part of the Antarctic Peninsula can also be found in many locations of the Andean orogenic plate forming the peninsula as far as Marie Byrd Land at its base, and even within the Transantarctic Mountains. Many of the Cenozoic volcanoes in the Antarctic were likely to have been active during the Ice Age, within the last 50 or so million years. The northern end of the Antarctic Peninsula is home to cones and calderas which are evidence of the most recent volcanic activity. Deception Island is a volcanic caldera where the most recent eruption took place in 1970, while the almost 4000-meter Mount Erebus, which erupted most recently in 2014, is on Ross Island near the East Antarctic coast.

Analysis of the relationship between climate changes and the intensity of volcanism requires the age and type of eruption to be defined with a high degree of precision. This is a major challenge if only a single method is used. Although isotope dating is sometimes also known as absolute dating, it does not take into account the time it takes for eruption products to reach the surface. In fact they can be significantly older: since mineral particles are highly resistant to temperatures, their isotope ratios which define their age are set before the magma escapes to the surface. Secondary post-magma processes frequently appear to significantly reduce isotope age as defined by light isotopes such as K-Ar and 40Ar/39Ar. This means that it is necessary to use several methods to

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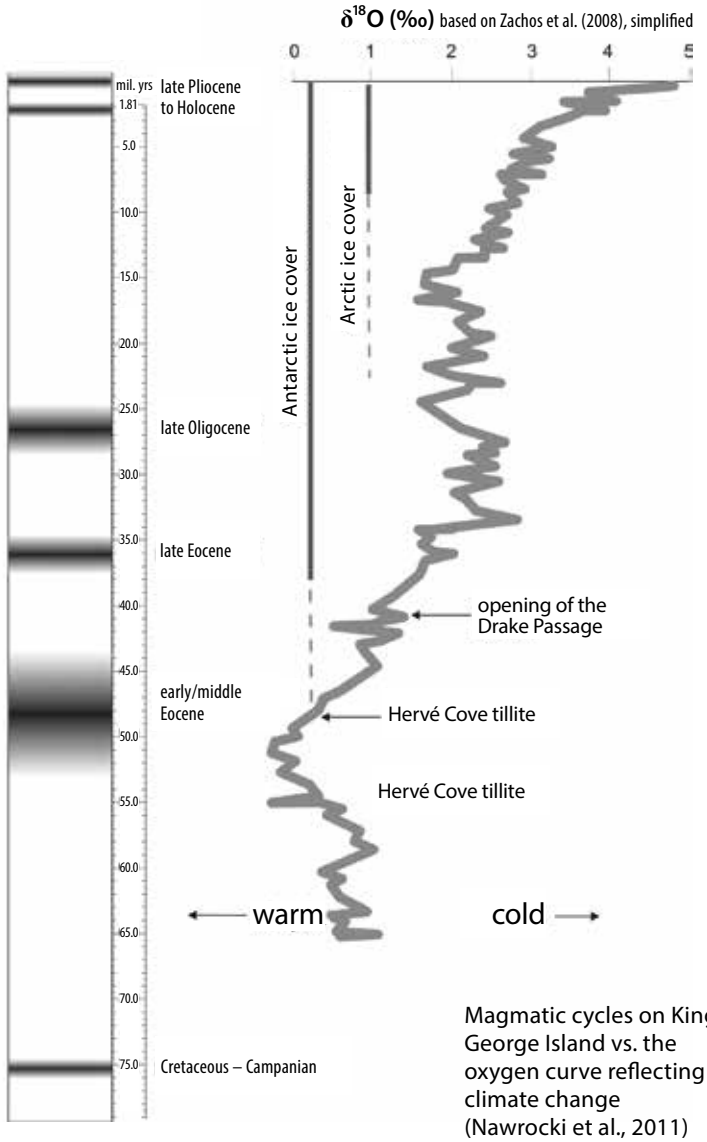

Magmatic cycles on King George Island vs. the oxygen curve reflecting climate change (Nawrocki et al., 2011)

establish the time of eruption with a high degree of precision. This was done in the studies of lava cover on King George Island, where researchers supplemented the studies of U-Pb and 40Ar/39Ar isotopes with magnetic stratigraphy.

Our microprobe

Some of the methods used to determine the age of volcanic rocks require state-of-the-art equipment. This is especially the case for pinpointing the isotope age of zirconium grains using the U-Pb method. We do such research using a sensitive high-resolution ion micro probe (SHRIMP) IIe made by Australian Scientific Instruments, used at facilities in Russia, Spain, and Poland. Our instrument was bought with funds from the Foundation for Polish Science and it is kept at the Micro-Area Analysis Laboratory of the Polish Geological Institute – National Research Institute. During the two years since its installation, the microprobe has been used to conduct point studies of stable isotopes such as oxygen and sulfur, which are important in the reconstruction of early climate and environmental conditions, as well as measuring uranium and lead isotope content.

Point measurements of zirconium age conducted in areas as small as 30 μm are essential since the mineral frequently has a band structure reflecting the many stages of its formation. The core of such a grain can be billions of years older than the outer layers, which are formed during its final journey to the surface in magma.

Polish researchers dating magma rocks from Western Antarctica also use magnetic stratigraphy, examining the changing polarity of Earth's magnetic field over the ages. The measurements, conducted at three well-equipped paleomagnetism laboratories in Poland, do not require specialist equipment for such measurements since magma rocks are powerfully magnetic. Finally, rocks are also dated precisely using a method based on the ratio of argon isotopes $^{40}Ar/^{39}Ar$, widely available at commercial laboratories.

Age is key

In the past, the ages of magma rocks from King George Island and the entire Western Antarctic were determined using K-Ar dating, which meant that the volcanic events were dated imprecisely. Results of the latest studies of volcanic formations on the island have allowed scientists to reconstruct several magma cycles, narrowed down to specific periods of geological age. The formations reach the greatest thickness at times corresponding to the development of moraine in Hervé Cove, which has led to the hypothesis that volcanism is likely to have affected the development of the Antarctic climate.

King George Island forms just a small part of the Western Antarctic which had been home to eruptions and effusion of volcanic rock over the last fifty million years. To demonstrate the influence of volcanic activity on the shaping of the Antarctic climate, research needs to be done over the entire area of Paleogene and Neogene volcanic formations. It is almost certain that our view of this volcanism, stretched over long periods and imprecisely dated, will change. It is likely that just a few cycles of volcanic activity will be identified, although it remains uncertain whether these continent-scale cycles will correspond to documented climate events. Will the type of volcanism prove to have been climatogenic: involving high emissions of ashes or greenhouse gases?

Jerzy Nawrocki

Further reading:

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