Shells - a unique climate archive on the ocean floor

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Most people who find a seashell during their summer holiday on the coast will probably not be aware that they have found a unique record of the climate. For Professor Bernd Schöne, however, these hard calcium shells provide a profound insight into the history of our earth and especially into the climate of the past.

"We are currently able to reconstruct the climatic history of the past 500 years from shells on a year-by-year basis. Thus we can demonstrate, for example, that the North Sea has become one degree warmer over the past hundred years, probably an effect attributable to humans," explains the palaeontologist from Mainz.

"Our discipline - molluskan sclerochronology - is still in its infancy. Before long, however, we shall know what climatic fluctuations took place in the North Sea and the North Atlantic in past millennia and what exactly has changed since then." Professor Schöne is head of Applied and Analytical Palaeontology at the Johannes Gutenberg University in Mainz. He hopes, in future, to be able to trace back the history of the earth even further. The shells themselves make this possible: Some of the oldest fossilized mollusk shells we find today originated 500 million years ago.

Shells are a unique climate archive. The shells have clearly delineated growth patterns that show changing nutritional conditions, temperature fluctuations and environmental pollution. Shells are found all over the world, in the polar regions and at the equator, on land and in the ocean,

in deeper waters and on ocean shelves, in tidal zones and in rivers, streams and lakes. "Shells are simply everywhere and, depending on their location, they provide us with important information about climatic developments. They serve as records of volcanic eruptions in Iceland or the occurrence of a hurricane in Florida; they can, for example, even tell us whether the early Indian tribes on the western coast of Canada collected mollusks during full moon, crescent moon or new moon periods," states Schöne. Even though many types of shell are durable and survive for thousands of years, the mollusks themselves are extremely sensitive: In the presence of environmental pollution, they respond by lowering their rate of shell growth, which is why they can also be used for longer-term monitoring of water quality.

The mussel known as the Icelandic cyprine is one of the favorite research objects of Professor Schöne and his team. Arctica islandica – as is its scientific name – occurs all over the North Atlantic in water depths of 20 to 400 meters. Until the value of the dollar fell, approximately 12,000 tonnes of these mussels were fished from the ocean around Iceland each year to supply the American and Japanese markets. The mussel fishers use dredgers shaped like oversized forks fitted with a net to plough up the ocean floor, where the mussels live half buried in the sediment. There are now only small numbers of Icelandic cyprines left in the North Sea. Their extreme longevity and slow rate of population recovery have been their undoing. Arctica islandica lives for up to 400 years and can be called the Methuselah of mussels, a circumstance from which scientists hope to benefit. "Icelandic cyprines provide extremely valuable, long-term records of environmental conditions and the changes that have occurred in the oceans," explains Professor Schöne. When dead mussels are found whose lifespans overlap with those of living individuals, the result is a cohesive picture of climatic history. In 2003, Schöne first used the Icelandic cyprine to prove that mussels record changes to the North Atlantic oscillation (NAO) - the climatic motor of the northern hemisphere. According to the information obtained, there

has been a trend towards milder winters since the 1960s - possibly the consequence of climatic changes caused by humans. He can also determine, however, how much of the greenhouse gas carbon dioxide is funnelled into the oceans and how much of this is the result of burning fossil fuels since the start of industrialization some 200 years ago. In the water, carbon dioxide forms an acid that can significantly hinder the formation of calcium skeletons - a dramatically increasing problem for the marine life of the future. For the first time, mussels can be used to accurately determine natural fluctuations in the CO2 content of the ocean in any specific year prior to the era of industrialization.

This accurate dating is possible because periodic growth lines, such as annual and even daily rings, are detectable in the shells. Mollusks thus produce, as it were, a kind of calendar in the form of their shells. The daily growth patterns are attributable to the same kind of biological clocks that make people wake up in the morning and become tired at night. In the case of the Icelandic cyprine, the trigger for the annual interruption in its shell growth is the reproductive phase, which reaches its peak about four weeks after the maximum summer temperatures. It appears that the mussel 'counts' these days after the seasonal temperature maximum and then releases eggs and sperm into the water. A special pattern can be seen in the case of mussels that live in tidal zones. They form two growth lines every day, each time at low tide. The shells only grow when they are covered by water, i.e. during high tide. The growth patterns of mussel shells excavated from ancient Indian kitchen middens in British Columbia can be used to determine whether the mussels were gathered at the full moon or at the crescent moon. "We are working in close cooperation with archaeologists to find out whether the Indians dived for the mussels or whether they simply garnered them at low tide, whether they collected them during the day or at night, and how far they went from the coast for them. All this information is provided by the mussel shells."

Professor Schöne investigates the shells by cutting them open with very fine diamond blades and then cutting out small portions, which are immersed in a dye bath. It is then possible to see a three-dimensional relief with clear blue growth lines. Mussel shells are made of composite materials, also known as biominerals, formed by the encapsulation of crystals in an organic framework. Also analyzed are the stable oxygen and carbon isotopes encapsulated in the calcium carbonate crystal lattice, together with the elements strontium, magnesium, and barium. State-of-the-art microanalytical methods that have only recently become available are used for this purpose. The status of isotopes and trace elements can, for example, be used to determine water temperatures and salinity.

Mussels are even being bred in the laboratories of the Department of Palaeontology in Mainz and are photographed with a digital camera at intervals of 15 seconds. "We are using this technique to verify whether they really have a daily biological clock. Some mussels, such as our local duck mussel, are only active for eight hours per day and only grow during that time, while their shells are half-closed the rest of the time and they can almost be said to be 'sleeping'. The activity and resting phases alternate with considerable chronological precision." These mussels are found all over the world and far outlive any other solitary living animal; they therefore store a large amount of climatic information. "The Pacific geoduck clam spends its entire life - typically well over 100 years - buried about 1 meter deep in sediment. After its death it remains at this depth and is thus a most valuable source of climatic information," says Professor Schöne. But there are also secrets to be discovered closer to home. About 28 million years ago, there was a narrow ocean channel stretching from the region around Basel as far as what is today the North Sea. The remains of mussels found here provide information about climate fluctuations and seasonal extremes. However far earth scientists manage to look back in time, their main interest is still in the here and now. Schöne summarises the research aim of sclerochronology as follows: "We want to investigate the natural climate

fluctuations before they were influenced by humans so that we can determine to what extent our climate differs today."

Source: University in Mainz