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Clam shells, climate change and ageing

The mollusc that had 500 birthdays

Key words
environment
mollusc
dating
ageing

In the summer of 2006, scientists collecting material from the seabed off the north coast of Iceland found some clam shells. Now, that doesn't sound all that exciting, but it turned out that they came from animals that were quite remarkably long-lived, several of them having lived for more than 300 years, and one that had lived for an amazing 507 years, making it the longest lived non-colonial animal whose age scientists have been able to measure accurately.

A live specimen of the mollusc Arctica islandica

The mollusc *Arctica islandica*

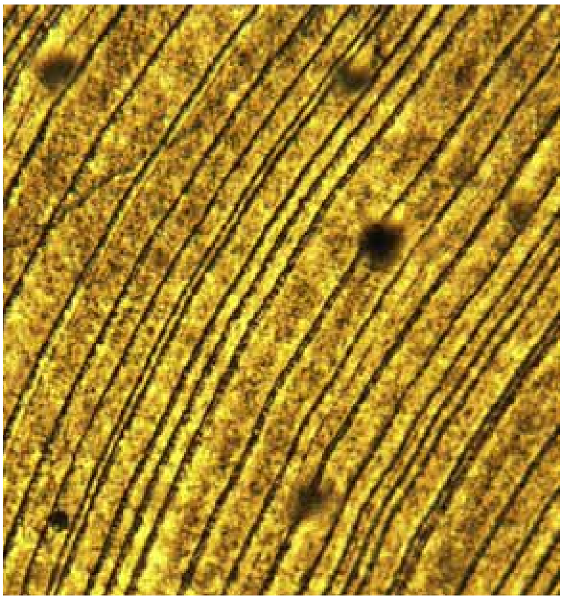
But why are these shells useful? Why do we spend money and time collecting them? Shells are what we call environmental proxies (see the box on page 8). That means that they are natural archives which record information about the environment within which they were formed. For example, by looking in detail at the chemistry of the calcium carbonate material that forms the shell, we can determine the seawater temperature when the shell was deposited. With extended records obtained from long-lived shells, we can get a useful picture of the recent history of global climate in the marine domain, one that goes back several centuries and includes the periodic cycles and long term trends that can help us to distinguish between the natural and human contributions to climate change.

The shells we found on that Icelandic trip come from a bivalve mollusc that lives buried in a wide range of sandy sediments and feeds by filtering food particles falling through the water. As its Latin name (*Arctica islandica*) suggests, it is very common around Iceland, but it is also found in most of the other shelf seas surrounding the North Atlantic Ocean. This makes it an especially promising archive for the study of marine climate, since the North Atlantic is the site of some of the key processes in the global ocean circulation, in particular the heat- and salinity-driven overturning that plays a crucial role in the global distribution of heat energy.

The distribution of Arctica islandica *around the North Atlantic ocean*

How old is that bivalve?

How do we know that these animals lived for hundreds of years? Shell growth in *A. islandica* is characterized by a short period every year (probably in late summer or autumn) when deposition of shell material becomes very slow or ceases altogether. When we take a cross section through the shell and look at the growth patterns internally under a microscope, this period shows up as a darker line, while a wider band of lighter material indicates the main growing season. We can record the amount of growth during each year by measuring the distance between the darker lines. When we do this with many shells from the same population, we find that that they grow synchronously. This shows, usefully, that they are all responding to the same environmental factors, and it also allows us to work out the dates of any dead shell we happen to find on the sea bed because we can compare its growth patterns with the patterns in shells from live caught animals whose date of death is known. (This technique, called 'crossdating', is derived from tree-ring research.) As a result, we can extend the period we can study back in time, potentially for many thousands of years.



Bands in the shell of Arctica islandica *allow us to age it just like we can with trees using tree-rings*

Shell interpretation

What information can we get from the shells? Having created an archive of precisely-dated shell material, the next challenge is to tease out some useful information about the environment.

First, we can investigate the width of the growth increments. This is just an indication of how much shell material the animal was able to produce in a single year. The most direct relationship is probably with food supply, but it may also record other factors, such as seawater temperature or the presence of ice at the sea surface, especially in regions where the animal is stressed by one of those factors.

A specimen from a recent dredging exercise near Iceland

Another approach is to look at the composition of the shell material itself. The different isotopes of oxygen and carbon can be measured with great precision and these analyses can tell us about seawater temperature, salinity and nutrients at the time of shell deposition. They can also help us investigate more complex aspects, such as changes through time in the original source of local water masses or in the uptake of fossil fuel carbon from the atmosphere into the marine environment.

Finally, the concentrations of other elements in the shell (calcium, strontium, magnesium, boron, zinc and many others) can be measured and compared, and these analyses can be used to investigate, for example, marine pollution and ocean acidification.

What have we found out?

We have been able to use radiocarbon measurements in the shell to show how the source of ocean water north of Iceland has changed over the past thousand years from a predominantly Atlantic origin to a predominantly Arctic origin, and that there are indications that this trend may have reversed in recent decades, possibly linked to modern global warming. We have also been able to use carbon isotopes in the shell to show how the uptake of fossil fuel carbon from the atmosphere into the ocean has changed during the past few hundred years. Up until now the ocean has been a major sink for anthropogenic ('man-made') carbon, and long term records such as that provided by *A. islandica* will help us to detect any signs that the oceanic sink is becoming saturated.

Clams are also dredged for food.

Looking back

Our Iceland chronology goes back 1350 years, and we have also created one for the Irish Sea which goes back nearly 500 years. The potential to extend them depends on the availability of shell material further back in time, which in turn depends on the persistence of the population and the fate of the dead shells. *A. islandica* has been common in the shelf seas surrounding the North Atlantic ocean at least since the last glaciation (about 18 000 years), but it will be difficult to find shells from any single population to cover that whole period. More likely, a network of so-called 'floating chronologies' (shells with growth patterns which match each other but which cannot be linked to any live-collected shells) will be built up with the potential to be connected and correctly dated as more material comes to light.

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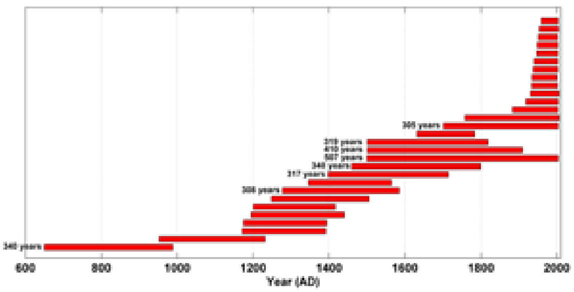
Environmental proxies

Instrumental observations of climate variables are now very precise and increasingly global in their coverage, but that hasn't always been the case. Even the most basic measurements of air temperatures only provide wide coverage for 100 years or so back in time. To find out about the climate before there were instrumental observations, scientists use proxies. These are natural archives that record something about the surrounding conditions under which they were formed. They include tree-rings, ice cores, corals and sediments in lakes and oceans. They can't always be dated accurately (for example, in a marine sediment core, we can only get a very rough approximation of the rate of sedimentation) but if they can be well-dated, we can get very useful information about when changes happened and the rate at which they happened.

Research into ageing

How long is *A. islandica* capable of living? We have found one animal that lived for more than 500 years, and several others that were more than 300 years old when they died. But the true answer to the question is that we just don't know. They appear to be able to switch off some of the usual processes of ageing (such as deterioration in muscle tissue and susceptibility to tumours) and it has been suggested that if they weren't eaten by predators they could in principle live forever. You won't be at all surprised to hear that *A. islandica* is now the focus of research aimed at finding out just how they manage to resist the ageing process.



Matching up shell bands allows us to tell when a clam lived and died. Each red band represents the lifespan of a single specimen.

Researchers are trying to understand the main determinants of the exceptional longevity of *A. islandica*; why does this species live so long? Identification of the mechanisms that delay or halt the ageing process in *A. islandica* would then enable research into the traditional model species to be directed towards the most productive areas.

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