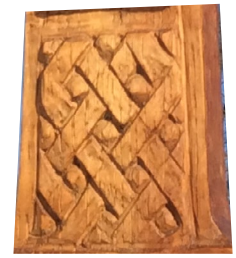
At Home on the Sea



Seashells and Global Climate

Can seashells be related to global warming and cooling?

They can, and this process is explained by Ward and Brownlee in a book called ***Rare Earth***, in which they explain that one of the little-considered conditions for the evolution of life is a world with subduction. Our Earth is rare in having this process, but without it, we would have died in a great Snowball, millions of years ago.

Seashells are composed of calcium carbonate, a compound that takes up carbon and locks it together with calcium to make a shell. When sea creatures die, their bodies decay and feed other critters in the ocean, but their shells fall to the ocean floor; thus the carbon in the shells stacks up there on the ocean floor. Over time, so much carbon is locked up that the natural greenhouse effect of carbon in the atmosphere is weakened and the earth becomes subject to something called the ice-house effect — or global icehouse — to ice ages, for example.

Global warming takes place for many reasons, including a periodic shift in the tilt of the Earth's axis, but another cause is the release of carbon compounds into the atmosphere. One contribution to this release is the burning of carbon compounds that had been locked up in plants by photosynthesis. Catastrophic worldwide burning seems to have taken place between the Mesozoic and Cenozoic eras in geologic history and at other times, perhaps. But burning is not the only way to release carbon.

The earth can also release the carbon compounds in seashells. It does this by pushing slabs of ocean floor under the continents in a continuous process called subduction. Deep under the continents, the seafloor melts, and the carbon compounds of the now-ancient seashells are released as carbon dioxide. But how is this great bubble of carbon dioxide to find its way out of the earth? It looks for a vent, or perhaps a weakness in the crust where it can make a vent, and it explodes to the surface along with a lot of molten rock. Subduction sends the ocean crust hundreds of miles below the continental crust. We call its explosion into the air a volcanic eruption of course, and in this way, the carbon dioxide once sequestered in shells is returned to the atmosphere, potentially warming the climate worldwide. I say "potentially" because there are other compounds, such as sulfurs, that may also come up and these have a cooling effect.

People have much to say about global warming in the 21st century, but over a long history, the Earth has at times been much warmer than it is now, and at other times, much colder, even an icehouse condition before the Cambrian revolution. (Maybe 150 million years before!) Even when Leif Erickson sailed across the ocean, it was warmer than today; and it was colder than today through much of the 16th century. This is just to say that there is another interesting climate factor to think about.

Photosynthesis in the Sea

Photosynthesis is the way that plants make sugars from water, carbon dioxide, and the action of sunlight. These sugars, as well as other carbohydrates, are the beginning of the food chain, all the way up through the animal kingdom. Let's review photosynthesis.

At the molecular level, water is composed of two hydrogen atoms and one oxygen atom. Carbon dioxide is composed of two oxygen atoms and one carbon atom. The green plants have a very large and complex molecule called chlorophyll which works with a few handfuls of the very small molecules of water and carbon dioxide to make a larger and more complex molecule, a sugar or other carbohydrate, composed of hydrogen, oxygen, and carbon. Notice that the word "carbo-hydrate" has the root carbon in it, and the root hydrate, which suggests that it is carbon combined with water. That is exactly what the chemical reaction produces: a hydrated carbon. There is also some extra oxygen which is released.

We write it out like this:

$6\ CO_2 + 6\ H_2O$ (+ sunshine) => $C_6H_{12}O_6 + 6\ O_2$

See how you have six carbon atoms on both sides of the equation, and 18 oxygen atoms, and 12 hydrogen atoms. The thing you can't see is that energy of the sun is needed to make this happen, and afterwards, that energy is locked up in the carbohydrate. Then when animals breathe oxygen and eat the carbohydrates, they reverse the system, using the energy to live, and breathing out the water and carbon dioxide. You live by unwrapping sunlight from your vegetables! (And all your other foods.)

Photosynthesis happens in the trees and other plants on land, but of course it also happens in the sea. Seaweed and algae and a tiny sea-plant called plankton all carry on photosynthesis. This causes the seawater to be supplied with oxygen. Then the fish can eat the weeds for food and pull the seawater through their gills to get oxygen.

Photosynthesis is always covered in biology books; probably you have heard of it many times, but calcium carbonate is less known.

Calcium Carbonate

Once the sea creatures have consumed the sea plants, they give off carbon dioxide, just as we do, and it mixes with the water. Some goes into the air; some stays dissolved in the water.

Some of the carbon dioxide that stays in the water makes a carbonate ion, (a charged particle that's carrying two extra electrons), and two hydrogen ions, hydrogen atoms that have lost their electrons. Then the little sea creatures combine the carbonate ion with a calcium ion, which is missing two electrons, and it makes calcium carbonate for their shells. This protects them from creatures that might eat them if they were too soft. Here is the reaction:

$Ca_2^{+} + 2CO_3^{2-} = 2CaCO_3$

So that is how seashells are made, though the actual steps are more complex.

Even the creatures that eat snails do not eat their shells. The shells of snails and clams and everything else get banged around a lot, and sometimes crunched by the animals that are eating the little soft critters inside. But they do not get digested. So they slowly fall to the ocean floor, where they sit and wait. Over time, and if they are near the shore, they may be covered with sand and filled with sand and other sediments from the rivers if they are near a continent. Or they may just accumulate. The weight of everything falling on the ocean floor gradually builds up and at last they are buried deeply, making a thick layer on the ocean floor. It all presses together so that the shells become a rock, instead of a sand pile.

A rock that is composed entirely of shells is called limestone.

Sometimes the limestone is lifted up from below and becomes land, making great chalky white ground, such as we see in the White Cliffs of Dover. Or a shelly rock might be pressed from opposite sides as it encounters land, as has happened in Italy, and then it will be pressed together even harder and become marble. Sometimes, in a church with marble floors, you can see the little curving sea creatures fossilized in the marble. They are much older than the churches!

They are beautiful and they continually honor God with their beauty.

Subduction

Sometimes the shelly sea floor is not lifted up as land but is pushed underneath the land.

Why is this?

It happens because the sea — the ocean — is constantly getting a new floor from the center, or from other volcanic areas. If you could take all the water out of the Atlantic Ocean you would see a great ridge in the center of the ocean floor. Other oceans also have ridges in different patterns. In some places, this ridge marks a line of volcanic action, continually pouring lava up into the sea. The force of this volcanic activity builds up the nearby ridges, but also it actually pushes the ocean floor away. (Slowly.) And when the ocean floor is pushed aside, it bumps into the continents, (Very Slowly) — and then what? Well, different things, but one is that it can dive under the continent and get buried. It dives under because ocean floor is heavier than continental crust.

Well, not *just* buried. What would happen if a piece of stone got pushed deep under the Earth?

The ocean floor is pushed under at a slant. It goes very deep, miles and miles deep, hundreds of miles, and at last the stone melts from the great heat inside our Earth. This would happen to any stone, because the magma below the crust of the Earth is very hot, and hotter as you go deeper. The whole center of the Earth is molten nickel and iron, and a little farther up, there is some uranium and other heavy elements mixed in. These heavy elements are unstable, and when they break apart, they release heat which makes the inside of the Earth even hotter. Gradually, the heat rises through the molten interior of the Earth until it reaches the surface where it can blow away. But first the heat travels through several zones of dense rock which is all melted by the heat from the below.

So if the shelly sea-floor is pushed deep into the magma, it melts, though it doesn't melt all at once. For a long time, it is still moving, deeper in and farther under the continent. When it is all melted, and the carbon dioxide is released from the shells, then there is a great bubble underground. What do bubbles do? They rise to the top, right?

In rock soup, it is hard for a bubble to rise, and besides, this soup has a crust on top. That's where we live. So our bubble rises as high as it can, but it cannot easily find a way out.

Global Cooling; Global Warming

Meantime, the atmosphere is losing so much carbon dioxide, first to the plants and then to the shells, that it is changing. Carbon dioxide is one of the molecules that helps the atmosphere trap heat on the earth. We call it a "greenhouse gas" because it keeps the heat in just as the glass windows of a greenhouse keep the heat in so you can grow things during the winter. (Water is the other main greenhouse molecule, and there are others as well.)

When the carbon dioxide is removed from the air and not returned, the Earth begins to lose heat a bit faster, sometimes faster than it can absorb heat from the sun. Then the earth becomes cold. If this goes on for a very long time, the northern parts of the earth (and the far southern parts — the poles) cannot melt all their winter snow, even by the end of summer. So the snow begins to accumulate at the poles and also in high places that stay cold longer. This is how glaciers form, and how the earth enters an ice age. It just keeps getting colder. Then the ice reflects the sunlight, and it cools even faster. We call it global cooling, and if it gets out of control, we call it runaway icehouse or "Snowball Earth." This has happened several times in the past.

Of course, as our Earth gets colder, the photosynthesis slows down, and then so does the growth of sea creatures which need plants to eat. So the carbon dioxide is no longer taken from the atmosphere quite so fast, but still, how is it to be returned?

Giving Back the Carbon Dioxide

There are several ways to give back the carbon dioxide. One is to dig up the old plants (the very old ones will have turned to coal) and burn them. Or just burn the trees without waiting for them to be coal; both men and forest fires do this.

But there is another way that nature can bring back some of the carbon. That great bubble of carbon dioxide from the shells melting in the magma can find a volcano and burp right out. Poof! There's the carbon dioxide high up in the air, making the earth warm again. It gets warmer and warmer, and the snow melts at last. This is called global warming, and it makes photosynthesis speed up, which sequesters the carbon again, in carbohydrates and seashells, and then Earth cools down again. It is a cycle that goes round and round.

You hear a lot about global warming. Mostly, in the cold place where I live, we are glad about it, if it is really happening, which is not at all clear. But of course it is troublesome if it happens very fast and you are living by the ocean because the water level of the ocean will actually rise if all the glaciers and the ice caps melt as they have certainly done in the past. The ocean rose 300 feet around the time of the Black Sea Flood, a few thousand years before Christ. Our cities that are close beside the ocean will have big problems if the ocean rises. In fact, the climate of the whole world will change if the ice caps melt. Greenland might become green again, as it was when Leif Erickson found it. Wouldn't that be amazing? Perhaps people could live there again, during an episode of global warming.

Magnitudes

It's easy to get the impression that the different things we have talked about — the atoms, the molecules, the seashells, the ocean, — are like the parts of a jigsaw puzzle. The ocean is like the puzzle, and the shells are the pieces and their knobs are like the atoms and molecules. It's easy to forget, or simply never to have learned, how different the sizes of these things really are.

An atom will sit on a snail shell, not like a knob on a puzzle piece, but like a snowflake on Mount Everest.

Even an entire unit of the mineral calcium carbonate will sit on a clamshell like a snowflake on Mount Everest, or like a fleck of dust in a city. (We call the smallest bit of calcium carbonate a unit of a mineral instead of a molecule because minerals just keep building wherever they begin; they don't wait for a whole molecule to assemble before taking it in.) Anyway, the building blocks are incredibly small.

And then the ocean is quite large. You know this from seeing the globe — the Pacific is nearly half the globe all by itself. But the globe is very small compared to the earth, and we can forget that, looking at a basketball-sized globe all the time.

A clamshell sits in an ocean the way a snowflake sits on Mount Everest. Now we are looking at the proportions the other way.

An atom is 10^{-10} meters in diameter.

A snail shell is 10^{-2} meters in diameter. Eight orders of magnitude larger than the atom!

A unit of a mineral is something like 10^{-9} meters in diameter, seven orders of magnitude less than the snail shell.

A clamshell is 10^{-1} meters in diameter, eight orders of magnitude larger than the mineral unit.

The ocean is about 10^{7} meters in diameter, eight orders of magnitude larger than the clamshell.

Eight orders of magnitude is about the size difference between a very small snowflake and Mount

Everest. We can also compare it to the difference between a fleck of dust and a medium sized city, one that's 6 miles in diameter.

Understanding magnitude is one thing, but becoming familiar with magnitude gives you a better feel for what kind of things are going on in the wide world. Eight orders of magnitude is about the largest magnitude jump that you can really understand because both ends of the jump are part of your life: 10^{-4} the smallest thing you can see without glasses, while 10^{4} is the largest thing you could easily walk across. It's about six miles, which is just a little more than the height of Mount Everest.

Your Measuring Rod

From 10^{-4} to 10^{+4} is a jump of eight orders of magnitude. Using this rod, you can understand the sizes of things, and then they become part of the way you are at home on our rare Earth.

So 10^{-4} to 10^{+4} is your measuring rod.