The Earth's secret history written and what it can tell us about climate change

Deep under the ocean, beneath the waves, creatures, and even the darkness of the deep sea is Earth's secret history. It lies in the sea floor, the compacted layers of sediments made of the broken down shells and skeletons of ocean life. If you know how to read these sediments, they are Earth's autobiography — and either reassurances or warnings for the future.

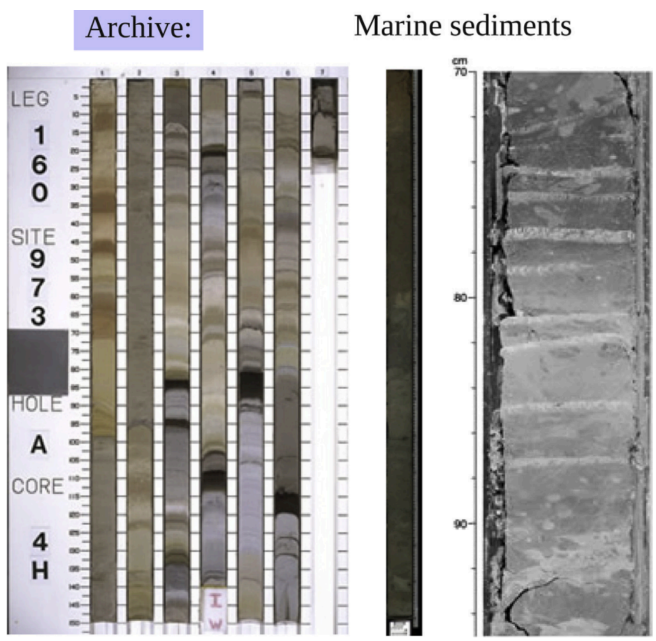

Figure 1: Picture of a Sediment Core[1]

Why decode this autobiography written in a language we don't understand? What could it tell us? One particularly useful thing it can give us is a record of the Earth's temperature. Helpful, given that the Tyrannosaurus Rex is not known for its ability to use a thermometer. Defining if and how the Earth's temperature has varied across the millennia can in turn help us understand how unprecedented our current climate's changes are.

[1] Evans et al., 2013.

The key to reading this history lies in oxygen. Though we breathe it in its diatomic form, it's also a key component of calcium carbonate ($CaCO_3$), which makes up the shells and skeletons of many sea creatures. When these creatures die, parts of their structures can sediment on the ocean floor. As this process repeats, the layers of sediment grow. Interestingly, the layers are not all the same, because the calcium carbonate that comprises them can differ slightly from layer to layer. This difference is caused by the calcium carbonate having different ratios of two types of oxygen. These types of oxygen are ^{18}O and ^{16}O, called "isotopes" of oxygen. Though the difference is subtle, the effect is mighty[2].

To understand how exactly we can "read" the sediments, we first have to understand the difference between ^{18}O and ^{16}O. ^{18}O has ten neutrons, as opposed to the eight that ^{16}O has. This means it is heavier. Though this change may not seem important, it can affect the way the chemical bonds the oxygen forms vibrate. Imagine a chemical bond to be like a spring — it can stretch and contract. Atoms are like weights on either end of that spring. A heavier weight at the end of the spring means that it will take longer for the spring to expand, contract, and return to its original position. The same thing happens with ^{18}O — the bonds it forms vibrate more slowly than the bonds that ^{16}O forms. In chemical terms, we would say that this bond has a lower "zero point energy." This lower energy means that the bonds are more stable. The effect of lowering energy grows in our sea sediment context, where oxygen is equilibrating (being transferred back and forth between) the ambient seawater and calcium carbonate.[3] This is because ^{18}O will be better stabilized by the lattice of calcium carbonate than by the

[2] Grossman 2012.
[3] Grossman 2012.

bonds in water. The double lowering of energy of ^{18}O in calcium carbonate means that ^{18}O will be most stable in it and accumulate there.[4]

What does this have to do with temperature? It turns out that this process of ^{18}O and ^{16}O equilibrating between seawater and calcium carbonate varies as a function of temperature at which it takes place. At lower temperatures, the accumulation of ^{18}O relative to ^{16}O is more pronounced, and we see a bigger difference between ^{18}O and ^{16}O levels relative to the seawater around it. Scientists have been able to figure out a relationship between the ratio of ^{18}O to ^{16}O and the ambient temperature. As a result, when they analyze the isotope ratio of ^{18}O to ^{16}O from these "autobiographical" sediments that document earth's many eras, they are able to infer the ambient temperature.[5,6]

This process, called "paleothermometry," like this has revealed many fascinating things. Among them is that the Earth has been hotter than it currently is, in times like the Cretaceous Hot Greenhouse period and Paleocene-Eocene Thermal Maximum. Before climate change deniers rejoice and claim that current changes in temperature are therefore unimportant, though, it's important to read the fine print. The earth has been this hot before, but the amount of time it took to heat up to this point was substantially longer.[7] So, while the temperature itself isn't remarkable on a geologic time scale, the rate at which it's increasing very much is.[8] In terms of earth's biography, we humans are causing a sharp plot twist. And though many of us want to make our mark on history, on the geologic time scale, it's probably best to be utterly unremarkable.

[4] Bigeleisen 1965.
[5] Epstein et al., 1953.
[6] Grossman 2012.
[7] Scott and Lindsey, 2025.
[8] Scott and Lindsey, 2025.

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