Scientists trace atmospheric rise in CO2 during deglaciation to deep Pacific Ocean

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Long before humans started injecting carbon dioxide into the atmosphere by burning fossil fuels like oil, gas, and coal, the level of atmospheric CO2 rose significantly as the Earth came out of its last ice age. Many scientists have long suspected that the source of that carbon was from the deep sea.

But researchers haven't been able to document just how the carbon made it out of the ocean and into the atmosphere. It has remained one of the most important mysteries of science.

A new study, published today in the journal *Nature Geoscience*, provides some of the most compelling evidence for how it happened—a "flushing" of the deep Pacific Ocean caused by the acceleration of water circulation patterns that begin around Antarctica.

The concern, researchers say, is that it could happen again, potentially magnifying and accelerating human-caused climate change.

"The Pacific Ocean is big and you can store a lot of stuff down there—it's kind of like Grandma's root cellar—stuff accumulates there and sometimes doesn't get cleaned out," said Alan Mix, an Oregon State University oceanographer and co-author on the study. "We've known that CO2 in the atmosphere went up and down in the past, we know that it was part of big climate changes, and we thought it came out of the deep ocean.

"But it has not been clear how the carbon actually got out of the ocean to cause the CO2 rise."

Lead author Jianghui Du, a doctoral student in oceanography at Oregon State, said there is a circulation pattern in the Pacific that begins with water around Antarctica sinking and moving northward at great depth a few miles below the surface. It continues all the way to Alaska, where it rises, turns back southward, and flows back to Antarctica where it mixes back up to the sea surface.

It takes a long time for the water's round trip journey in the abyss—almost 1,000 years, Du said. Along with the rest of the OSU team, Du found that flow slowed down during glacial maximums but sped up during deglaciation, as the Earth warmed. This faster flow flushed the carbon from the deep Pacific Ocean—cleaning out Grandma's root cellar—and brought the CO2 to the surface near Antarctica. There it was released into the atmosphere.

"It happened roughly in two steps during the last deglaciation—an initial phase from 18,000 to 15,000 years ago, when CO2 rose by about 50 parts per million, and a second pulse later added another 30 parts per million," Du said. That total is just a bit less than the amount CO2 has risen since the industrial revolution. So the ocean can be a powerful source of carbon.

Brian Haley, also an Oregon State University oceanographer and co-author on the study, noted that carbon is always falling down into the deep ocean. Up near the surface, plankton grow, but when they die they sink and decompose. That is a biological pump that is always sending carbon to the bottom. "The slower the circulation," Haley said, "the more time the water spends down there, and carbon can build up."

Du said that during a glacial maximum, the water slows down and accumulates lots of carbon. "When the Earth began warming, the water movement sped up by about a factor of three," he noted, "and that carbon came back to the surface."

The key to the researchers' discovery is the analysis of neodymium isotopes in North Pacific sediment cores. Haley noted that the isotopes are "like a return address label on a letter from the deep ocean." When the ratio of isotope 143 to 144 is higher in the sediments, the water movement during that period was slower. When water movement speeds up during warming events, the ratio of neodymium isotopes reflects that too.

"This finding that the deep circulation sped up is the smoking gun in this mystery story about how CO_2 got out to the deep sea," Mix said. "We now know how it happened, and the deep Pacific is the culprit—a partner in crime with Antarctica."

What concerns the researchers is that it could happen again as the climate continues to warm.

"We don't know that the circulation will speed up and bring that carbon to the surface, but it seems like a reasonable thing to think about," Du said. "Our evidence that this actually happened in the past will help the people who run climate models figure out whether it is a real risk for the future."

The researchers say their findings should be considered from a policy perspective.

"So far the ocean has absorbed about a third of the total carbon emitted from fossil fuels," Mix said. "That has helped slow down warming. The Paris Climate Agreement has set goals of containing warming to 1.5 to 2 degrees (Celsius) and we know pretty well how much carbon can be released to the atmosphere while keeping to that level.

"But if the ocean stops absorbing the excess CO_2, and instead releases more from the deep sea, that spells trouble. Ocean release would subtract from our remaining emissions budget and that means we're going to have to get our emissions down a heck of a lot faster. We need to figure out how much."

More information: [26] Flushing of the deep Pacific Ocean and the deglacial rise of atmospheric CO_2 concentrations, *Nature Geoscience*

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