How seafloor weathering drives the slow carbon cycle

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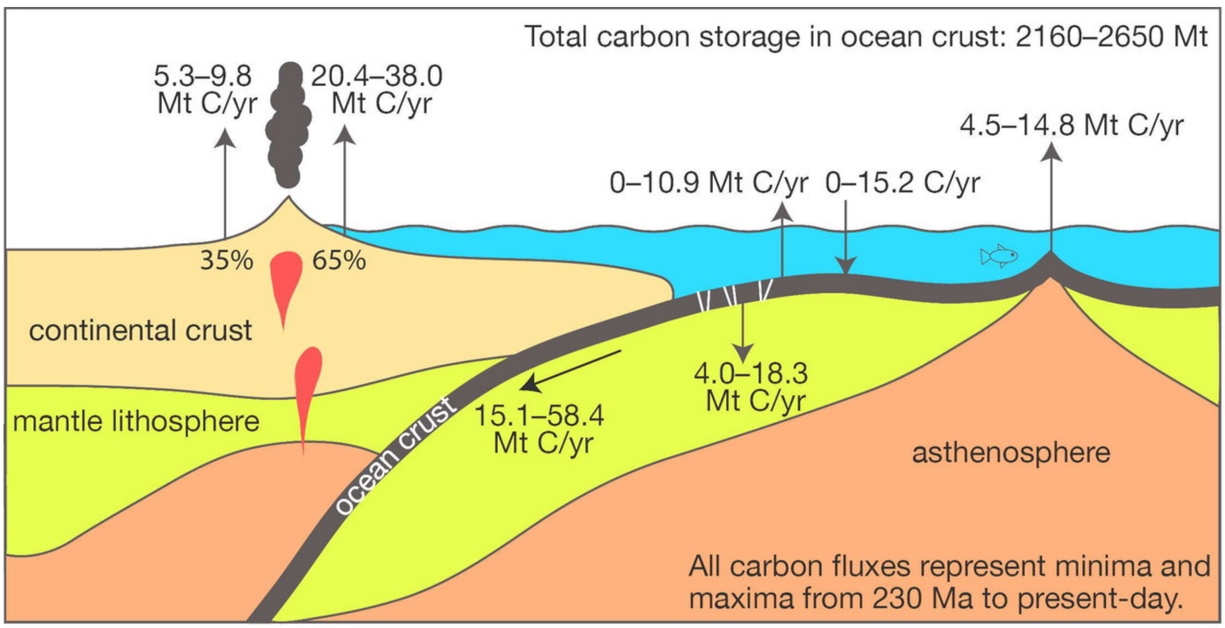

The oceanic slow carbon cycle. Credit: Adriana Dutkiewicz

A previously unknown connection between geological atmospheric carbon dioxide cycles and the fluctuating capacity of the ocean crust to store carbon dioxide has been uncovered by two geoscientists from the University of Sydney.

Prof Dietmar Müller and Dr Adriana Dutkiewicz from the Sydney Informatics Hub and the School of Geosciences report their discovery in the journal *Science Advances*.

Many of us are familiar with the Slow Movement philosophy, which includes slow living, slow cooking, slow fashion, and even slow TV. But most of us would not have heard of the slow carbon cycle, which is about the slow movement of carbon between the solid Earth and the atmosphere.

The slow carbon cycle predates humans and takes place over tens of millions of years, driven by a series of chemical reactions and tectonic activity. The slow carbon cycle is part of Earth's life insurance, as it has maintained the planet's habitability throughout a series of hothouse climates punctuated by ice ages.

One idea is that when atmospheric carbon dioxide rises, the weathering of continental rock exposed to the atmosphere increases, eventually drawing down carbon dioxide and cooling the Earth again.

Less well-known is that weathering exists in the deep oceans too. Young, hot, volcanic ocean crust is subject to weathering from the circulation of seawater through cracks and open spaces in the crust. Minerals such as calcite, which capture carbon in their structure, gradually form within the crust from the seawater.

Recent work has shown that the efficiency of this seafloor weathering process depends on the temperature of the water at the bottom of the ocean—the hotter it is, the more carbon dioxide gets stored in the ocean crust.

Prof Müller explains: "To find out how this process contributes to the slow carbon cycle, we reconstructed the average bottom water temperature of the oceans through time, and plugged it into a global computer model for the evolution of the ocean crust over the past 230 million years. This allowed us to compute how much carbon dioxide is stored in any new chunk of crust created by seafloor spreading."

Dr Dutkiewicz adds: "Our plate tectonic model also allows us to track each package of ocean floor until it eventually reaches its final destination—a subduction zone. At the subduction zone, the crust and its calcite are recycled back into the Earth's mantle, releasing a portion of the carbon dioxide into the atmosphere through volcanoes."

The computer model reveals that the capacity of the ocean crust to store carbon dioxide changes through time with a regular periodicity of about 26 million years.

Several geological phenomena including extinctions, volcanism, salt deposits and atmospheric carbon dioxide fluctuations reconstructed independently from the geological record all display 26 million-year cycles.

A previous hypothesis had attributed these fluctuations to cycles of cosmic showers, thought to reflect the Solar System's oscillation about the plane of the Milky Way Galaxy.

Prof Müller says: "Our model suggests that characteristic 26 million-year periodicity in the slow carbon cycle is instead driven by fluctuations in seafloor spreading rates that in turn alter the capacity of the ocean crust to store carbon dioxide. This raises the next question: what ultimately drives these fluctuations in crustal production?"

Subduction, the sinking of tectonic plates deep into the convecting mantle, is regarded as the dominant plate driving force of plate tectonics. It follows that cyclicities in seafloor spreading rates should be driven by equivalent cycles in subduction.

An analysis of subduction zone behaviour suggests that the driving force in the 26 million-year periodicity originates from an episodicity in subduction zone migration. This component of the slow carbon cycle needs to be built into global carbon cycle models.

Better understanding of the slow carbon cycle will help us predict how the Earth will react to the human-induced rise in atmospheric carbon dioxide. It will help us answer the question: To what extent will the continents, oceans and the ocean crust take up the extra carbon dioxide in the long run?

More information: R.D. Müller el al., "Oceanic crustal carbon cycle drives 26-million-year atmospheric carbon dioxide periodicities," *Science Advances* (2018). DOI: 10.1126/sciadv.aaq0500 , advances.sciencemag.org/content/4/2/eaaq0500

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