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Earth & Space

Carbonating the bottom of the ocean…and dissolving the seafloor with it

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ABSTRACT
Dissolving minerals such as calcium carbonate can buffer the ocean from having its acidity increased. There are many examples in the geological record, where the spreading of bottom waters enriched in carbon dioxide helped dissolve minerals delivered to the seafloor and contained within deep-sea sediments.

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Carbon dioxide (CO_2) in the atmosphere is absorbed by our oceans, and has an important impact on our oceanic ecosystems. When an ocean absorbs CO_2 in large quantities its chemistry changes, and it becomes more acidic. However, the oceans have their very own antacid: a mineral called calcium carbonate, which comprises the exteriors of some marine organisms – clams, oysters, starfish, coccolithophores, coral, and others. Like an antacid, these minerals help to buffer the acidity of the ocean by dissolving and producing a charged molecule called carbonate, which can effectively neutralize acid.

Interestingly, these organisms also have another important role in helping us to understand the past of our planet's climate. When they die and fall to the seafloor, they become one with the sediments. As thousands of years of sediment accumulate, layer after layer, a lot of information from our planet's past ecosystems and climates is stored in them, and can be retrieved by looking at what got deposited on the seafloor. But now, with the increase in ocean acidity, these sediment deposits are starting to dissolve more quickly, taking with them fascinating information about our planet's past that we'll perhaps never know.

Over the past two centuries, human-induced carbon emissions have been affecting our oceans, and we recently found that the effects of these emissions have not only reached the surface layers, but can actually be detected in the deep ocean. For this study, we invented a new interdisciplinary way to calculate how quickly calcium carbonate is dissolving due to ocean acidification, and applied it to study the deep ocean. First, we sailed ships to many locations on our world's oceans, and we took chunks of sediment – called cores – from the seafloor and samples of seawater from the deep ocean to measure the levels of calcium carbonate. Next, we did laboratory experiments to determine the conditions that would lead to slower or quicker dissolution of calcium carbonate. Then we used computer models to estimate the water currents near the seafloor because direct measurements of currents near the bottom are sparsely available. Finally, we developed mathematical equations that helped us to infer how the rate at which calcium carbonate falls to the seafloor and the rate at which it dissolves has changed in the past centuries. These equations relate the total amount of dissolved carbon dioxide, to the total capacity for the ocean to buffer acidity, to the rate at which calcium carbonate falls to the seafloor, and to the concentration of calcium carbonate at the seafloor.

At a certain depth, the rate at which calcium carbonate falls towards the seafloor matches the rate at which calcium carbonate is dissolved. We found that the depth at which this happens has become shallower since a few centuries ago.. Now, more of the water column has greater rates of dissolution, which explains why calcium carbonate is dissolving more quickly now than a couple of centuries ago. The locations of the greatest dissolution rate changes - the northwest Atlantic Ocean and the Southern Ocean - make sense, considering what is known about the general circulation of the ocean. The northwest Atlantic Ocean and the Southern Ocean are regions where water can efficiently get down from the surface to abyssal depths more quickly than any other region of the ocean. The bottom line is that the human-emitted carbon dioxide entering the ocean near Greenland and Antarctica has made it down to the bottom of the ocean. The new study is not saying the sky is falling; it's saying that the seafloor is dissolving.

More research needs to be done on how dissolution rates of calcium carbonate have changed over the course of the ocean's past history and how they will change in the future. Knowledge of past changes can help predicting future changes and inform policy for adaptation and/or mitigation purposes. For example, there are chemicals that can add buffering capacity - called alkalinity - against the increase in acidity. The extra alkalinity would actually allow more carbon dioxide to enter the ocean from the atmosphere, but a stomach can take only so much antacid in an eating competition. Additional investigations could help determine whether decreasing carbon dioxide emissions is the only viable technique to curtail the acidification problem. In the meantime, we will have to hurry before we lose access to Earth's history.