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

Scientists who depend on samples of sediments at the bottom of the ocean to understand the Earth's climate history may need to hurry up. Some marine organisms are comprised of material called calcium carbonate which can buffer the ocean from getting more acidic instead of carbon dioxide reacting with water in the ocean to produce carbonic acid. Calcium carbonate can dissolve in sufficiently acidic seawater, leaving a charged molecule called carbonate, which may react with the acid to effectively neutralize it. Basically, calcium carbonate in the ocean is similar to an Alka-Seltzer in someone's stomach. The organisms that are partially made up of calcium carbonate eventually die and can sometimes fall to the seafloor, becoming one with the sediments. Sediments are geological indicators of natural fluctuations in the acidity of the oceans long ago due to a combination of changes in carbon dioxide concentrations in the atmosphere, underwater volcano eruptions, and the decay of marine organisms. But these sediments can dissolve if the acidity increases enough at the bottom of the ocean.

Over the past two centuries, the most significant change in carbon dioxide introduced to the deep ocean has come from human emissions. Some people may try to carbonated liquids that were never meant to be carbonated, but it's less of a laughing matter to carbonate the ocean, which we now have evidence that we are doing to its bottom. A new study has shown that the increase in acidity relative to a couple of centuries ago is now detectable in some locations. The way this study investigated whether such a change was detectable required some new developments in the way that the rate at which calcium carbonate dissolves is calculated. Equations had to be derived for this rate, laboratory experiments had to be done to put constraints on the equations, expensive observational measurements had to be made off of the side of a boat to plug values into the equations, and computationally intensive simulations had to be performed to fill in the gaps of insufficient observations.

The key to calculating the rate of calcium carbonate dissolution in the new study was to know the carbonate concentration at the bottom of the ocean at two different times: a couple of centuries ago and more recently. The carbonate concentration at the seafloor can be inferred from the dissolved inorganic carbon - or sum of all products of carbon dioxide in seawater - and total alkalinity - or measure of how much buffering capability the ocean has based on its volume and acidity. Dissolved inorganic carbon can be calculated at the two different times from observations. On the other hand, the total alkalinity, the rate at which calcium carbonate rains down to the seafloor, and the currents near the bottom of the ocean were assumed to be constant over the past couple of centuries. To the best of our knowledge, if this assumption is thrown out, then the percent of the seafloor where the dissolution rate has increased can actually go up. In other words, the detected changes over the past couple of centuries in calcium carbonate dissolution rates are possibly underestimates, not exaggerations. And the changes are also larger than all known uncertainties.

The main finding of the new study is that the depth at which the rate of calcium carbonate raining down toward the seafloor becomes less than the rate of calcium carbonate dissolution has become shallower since a couple of centuries ago. More of the water column with greater rates of dissolution 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 provide context for the relative magnitude of the changes we have already observed. We could also assess the information that we may be losing due to the dissolution of sediments. Predicting future changes can help inform policy for adaption and/or mitigation purposes. For example, adding more alkalinity to the ocean could buffer the increase in acidity, but the extra alkalinity would actually allow more carbon dioxide to enter the ocean from the atmosphere. A stomach can take only so much Alka-Seltzer 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.