Erosion drives carbon dioxide emissions by weathering of rock-derived organic carbon

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Over geological timescales, the oxidation of organic carbon in sedimentary rocks is a major emission of carbon dioxide (CO_2) to the atmosphere. The global magnitude of this weathering flux remains poorly constrained, but it is thought to be similar to the CO_2 emissions from volcanism. The reaction kinetics of rock-derived organic carbon (‘petrogenic’ OC, OC_{petro}) have been measured in the laboratory, and appear to be ~10 x faster than those of silicate minerals driven by acid hydrolysis. This observation, linked to the high concentrations of O_2 in the present day atmosphere, mean that OC_{petro} oxidation rates are thought to be limited by mineral supply in many settings around the world. This is important because weathering-induced CO_2 release (by OC_{petro} oxidation) may increase with erosion, while weathering-induced CO_2 drawdown (by silicate mineral weathering by carbonic acid) can become kinetically limited where erosion rates and mineral supply rates are high. To constrain how the geological carbon cycle operates and modifies Earth’s climate over millions of years, we must better understand the controls on the oxidation of OC_{petro}.

Here we examine new and published constraints on OC_{petro} oxidation, which come from indirect measurements (e.g. trace element proxies such as rhenium) and direct measurements (e.g. CO_2 trapping and ^{14}C). Although published measurements are still sparse, they show that physical erosion plays a major role in setting OC_{petro} oxidation flux. They are interrogated in the framework of a catchment-scale numerical model of OC_{petro} oxidation. Key parameters emerge, such as the ‘weathering thickness’ which describes a depth to which oxidative waters penetrate (O_2 supply). The model predicts that the kinetic limitation of OC_{petro} oxidation is not reached until physical erosion rates exceed ~2 mm yr^{-1}, which is much higher than for CO_2 consumption by silicate weathering. Building mountains from sedimentary rocks should increase CO_2 emissions from OC_{petro} oxidation, and consume atmospheric O_2. The impact on global biogeochemical cycles awaits further investigation.