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The seawater calcium concentration may be a driver of long-term changes in CO_2

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The drawdown of CO_2 via the temperature-dependent weathering of silicate minerals is thought to be one of the key processes acting to maintain Earth's climate within narrow bounds over geologic time. However, the climatic responsiveness of weathering on multi-million-year timescales is, to our knowledge, yet to be demonstrated. If other factors dominate climate regulation on geologic timsecales, previously unexplored factors may be important in driving long-term carbon cycle changes. Here, we present the first continuous Cenozoic record of the concentration of calcium in seawater ($[Ca^{2+}_{sw}]$). Our record is based on the Na/Ca of exceptionally well-preserved foraminiferal calcite, a methodology which leverages the extremely long seawater Na^+ residence time (>40 Myr) to interpret such changes predominantly in terms of $[Ca^{2+}_{sw}]$ fluctuation. We show that a 12 mM decrease in $[Ca^{2+}_{sw}]$ occurred over the last ~50 Ma, with a close correspondence to the timing of atmospheric CO_2 changes, potentially implying a common driver. Using a carbon cycle box model, we demonstrate that, if the relationship between silicate weathering is shallower than commonly assumed, then this change in $[Ca^{2+}_{sw}]$ can mechanistically explain the majority of the Cenozoic CO_2 decrease, via the effect that Ca^{2+} has on $CaCO_3$ burial rates. Given the recently identified major change in the global sea floor spreading rate, this finding shifts the key driver of long-term climate from the terrestrial to marine realm. Conversely, if there is a steep relationship between silicate weathering and climate, the climatic responsiveness of weathering is such that the system would rebalance before $[Ca^{2+}_{sw}]$ can drive a major CO_2 change. Our results therefore highlight the need to determine whether silicate weathering is responsive to climate change on geologic timescales before the long-term drivers of CO_2 can be determined.