Sulfur isotopes track the amplitude and dynamics of global sea-level fluctuation since the mid-Cenozoic

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The mid to late Cenozoic marks a sea-level highstand to lowstand transition. Proxy records of seawater sulfate $\delta^{34}S$ inform the Cenozoic evolution of the sulfur cycle, but the absence of parallel, high-resolution records of marine pyrite $\delta^{34}S$ limits our understanding of the governing processes. We present high-resolution pyrite sulfur isotope data from both shelf and deep sediments of the eastern New Zealand margin (water depths of 3290 and 343.6 meters, respectively). Over the last 36 Myr, the deep basin sediments show low and invariant pyrite $\delta^{34}S$ (~–51‰ VCDT), whereas the shelf environment displays large stratigraphic variations (>60‰) in pyrite $\delta^{34}S$, in phase with high-frequency (41-100 kyr) changes in sea level. Interestingly, the amplitude of pyrite $\delta^{34}S$ oscillations on the shelf increases from ~60 to lower than 15‰ around 2 Ma, concurrent with the transition to a lowstand. This amplitude increase is driven mostly by an increase in the highest pyrite $\delta^{34}S$ values, preserved during high-amplitude sea-level lows.

The observed oscillations in shelf pyrite $\delta^{34}S$ cannot be explained by variation in Cenozoic seawater sulfate $\delta^{34}S$, which is not of the required magnitude or timescale. Instead, we suggest that variation in sedimentation rate in response to high-frequency sea-level changes resulted in a variable degree of diffusive communication between seawater and sediment porewater. Rapid sedimentation on the shelf during sea-level lows results in more "closed-system" microbial reduction and isotopic distillation of sulfate, and in burial of more ^{34}S-enriched pyrite. During the lowstand, high-frequency sea-level changes drive larger variations in diffusive exchange and pyrite $\delta^{34}S$. The absence of deep-water variation in pyrite $\delta^{34}S$ reflects minor coupling of offshore sedimentation rates with sea-level variations.

The preservation of high-$\delta^{34}S$ pyrite in shelf sediments during sea-level lows, and the increase in the highest pyrite $\delta^{34}S$ values preserved upon the transition to the lowstand should not be limited to the New Zealand shelf, and we suggest that they may explain the decrease in seawater $\delta^{34}S$ of ~2‰ observed since the mid Miocene.