Carbonate Associated Sulfate's journey along the "Elderfield curve"

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One of the most exciting questions in Earth science is to understand how biogeochemical cycles control the composition of the Earth's ocean-atmosphere system. Geochemical proxies provide a way to reconstruct the delicate balance that exists between geobiological processes and Earth's climate and environment. Critical parameters such as atmospheric O_2 and CO_2 levels leave only indirect traces in the sedimentary record. However, they are set by the interactions between the biogeochemical cycles of sulfur, carbon and oxygen, which also control the sulfur isotopic composition ($\delta^{34}S$) of seawater sulfate, one of the main superficial reservoirs of sulfur.

As a result, the $\delta^{34}S$ of seawater sulfate provides crucial insights into Earth's environmental history, and reconstructing its variations through geologic time has been the object of significant efforts over the last 30 years. There are mainly three $\delta^{34}S$ archives: sulfate from evaporites (gypsum and anhydrite), sulfate from barite, and carbonate associated sulfate (CAS). CAS is the only archive offering near-continuous temporal and environmental coverage. The first measurements of CAS developed a strong sense of optimism and many investigations of sulfur isotopes in bulk carbonate rocks, micrites and brachiopods established a much clearer vision of the Phanerozoic and Precambrian sulfur cycle than what was previously possible with sulfur isotopes recorded in evaporites. However, the CAS record appears significantly noisier than the barite record and the fidelity of CAS as a proxy for seawater sulfate was questioned, leading the field towards a more pessimistic outlook. How is sulfur incorporated into the rock? Can any type of carbonate rock be used to measure CAS sulfur isotopes? Is there a preservation bias?

In this contribution we will show how collective efforts have increased our understanding of CAS, from atomic scale processes to paleoenvironmental reconstructions, making carefully analyzed CAS a realistic and fidel proxy for the $\delta^{34}S$ of seawater sulfate.