Negative sulfate ^{17}O anomalies as positive evidence for "Snowball Earth" hypothesis

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Since the discovery of a common occurrence of sulfate ^{17}O anomaly in Earth's continental deposits, a considerable amount of triple oxygen isotope data has been gathered for sulfate of diverse origins over the years. Without exception, until now all $\Delta^{17}O$ values are positive, reaching as high as +5.84‰. It is known that the positive ^{17}O anomalies are ultimately transferred from that of atmospheric ozone. This new parameter has proven to be powerful in sulfate source identification and quantification in geological, environmental, and atmospheric problems.

Here I present a large set of sulfate $\Delta^{17}O$ data for marine evaporites and barites, which have had no direct link to atmospheric ozone chemistry. The data reveal variable negative $\Delta^{17}O$ values among sulfates of different occurrences or ages. Specifically, sulfate $\Delta^{17}O$ values lower than −0.20‰ are common in the lower Cambrian around the world (e.g., Siberia, Australia, and India) while none in the late Paleozoic or modern settings. Most remarkably, barites from the Marinoan cap carbonate sequences deposited ~ 635 million years ago possess a spike of extremely negative $\Delta^{17}O$ values. Values lower than −0.40‰ are found in both northwestern Namibia and South China.

I propose that the triple oxygen isotope composition of shallow marine sulfate carries a portion of the tropospheric O_2 signal, which has had variable negative $\Delta^{17}O$ values that were determined largely by stratospheric O_3-CO_2-O_2 chemistry. A quantitative relationship between atmospheric conditions and the $\Delta^{17}O$ of atmospheric O_2 requires a comprehensive atmospheric model. If we assume that the $\Delta^{17}O$ of air O_2 scales roughly linearly with pCO_2, as is supported by published glacial and interglacial data, the marine sulfate $\Delta^{17}O$ data suggest that pCO_2 was much higher in Early Cambrian than in younger era, agreeing with previous modelling results. Most significantly, the negative sulfate $\Delta^{17}O$ spike in the Marinoan cap carbonate sequences points to an extremely high pCO_2 at the immediate aftermath of a global deglaciation, supporting the Neoproterozoic 'snowball' Earth hypothesis. An on-going survey in South China is expected to yield a better picture of this negative "spike".

Geochemical investigation of Kuhe - Dom Volcanic Rocks, central Iran

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The Urumieh-Dokhtar magmatic zone is a calc-alkaline magmatic arc of Eocene to Plio-Quaternary age. These magmatic arcs are linked to the subduction of the Neo-Tethys to the North below the Central Iranian Block. The Eocene volcano - sedimentary Rocks of Kuhe - Dom are located in Urmiyeh - Dokhtar magmatic belt in the northeast of Ardestan district, central Iran. The stratigraphic sequence is composed of lower Eocene Gorgab and Middle Eocene sahlab formations. The volcanic Rocks are olivine basalt, basalt, basaltic andesite, trachy basalt, trachy andesite, andesite, dacite, rhyodacite and rhyolite. The pyroclastics rocks are less common in this area and consist mainly of various types of crystal lithic tuffs and bereccias, which crystals are essentially plagioclases and lithic fragments are mainly basaltic-andesites and trachy-basalt-andesites. On the basis of major, trace and REE element diagrams, the Kuhe – Dom rocks show characteristics of calcalkaline series typical of Urumieh-Dokhtar magmatic belt. Petrological and geochemical investigations demonstrate that the Kuhe – Dom Volcanic Rocks are high – K, Meta – aluminous and are consistent to continental arc environment.

References

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