Triple Oxygen Isotopes in Shales through time: Rapid Emergence of Subaerial Landmasses at 2.5Ga

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The history of continental crust growth is uncertain, and various models have been proposed that advocate gradual or stepwise growth. Even more uncertain is the timing and the secular trend of the emergence of most landmasses above sealevel that range from less than 1 to 3Ga. The area of emerged crust influences global climate feedbacks and the supply of nutrients to the oceans. It herefore connects surface environmental conditions to Earth's crustal evolution. Here, we use the triple-oxygen isotope composition ($\Delta'^{17}O$ - $\delta'^{18}O$) of shales from all continents and spanning 3.5 billion years to provide constraints on the emergence of continents through time. The combined use of triple oxygen isotopes and compositional parameters allows us to resolve temperature vs $\delta'^{18}O$ water effects and via numerical inversion solve for both parameters. Our measurements show a stepwise decrease of –0.08 ‰ in the average $\Delta'^{17}O$ value of shales across the Archean-Proterozoic boundary, in contrast to a more gradual increase in $\delta'^{18}O$. Also, Ti isotope and chemical compositions of a subset of studied shales suggest equal proportions of exposed mafic/silicic rocks undergoing weathering since 3.5Ga. We suggest that our data is best explained by a shift in the regime of water-rock interactions from near-coastal in the Archean to predominantly continental in the Proterozoic, accompanied by a decrease in the average surface temperatures. The inferred rapid increase in Earth's subaerial surface and overall hypsometry at 2.5 Ga would have also increased Earth's albedo, flux of nutrients to the oceans from the continents, and extent of continental margins, additionally resulting in a higher burial rate of organic carbon. In combination, these changes could have contributed to the Snowball glaciations of the early Paleoproterozoic, and the GOE, highlighting how Earth's interior could have influenced surface redox conditions and chemistry. Our study suggests that it might have been modulated by long-term cooling of the mantle and the emergence of extensive landmasses at the Archean-Proterozoic boundary, with life and surface conditions adjusting to, rather than triggering the change in surface conditions.