Extraordinary Neoproterozoic conditions implicated by sulfate of extraordinary oxygen isotopic compositions

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Among all the reported terrestrial sulfate oxygen isotope data, the $\delta^{18}O$ value ranges from ~+10‰ to ~+20‰ (all in VSMOW) for marine sulfate and down to ~−20‰ for sulfate recently formed in continental Antarctica. On the other hand, the $\Delta^{17}O$ value has been close to zero for marine sulfate but is in a positive spectrum (up to ~+5.90‰) for sulfate of atmospheric origin. All these ranges have been well explained by sulfate formation pathways and the corresponding environments. However, sulfate extracted from limestones and dolostones of the Neoproterozoic Wilsonbreen Formation, northeast Spitsbergen, Svalbard, breaks the current "envelope" of oxygen isotope compositions astoundingly on two fronts: the $\Delta^{17}O$ reaches as negative as −1.64‰ and the $\delta^{18}O$ as positive as ~+37.0‰. In addition, data from a spectrum of samples representing different degrees of evaporation (on the basis of the $\delta^{18}O_{carbonate}$) display a tight positive correlation in the sulfate $\delta^{18}O$–$\Delta^{17}O$ space as well as in the $\delta^{18}O_{carbonate}$–$\delta^{18}O_{sulfate}$ space. Interestingly, the $\delta^{34}S_{sulfate}$ only shows a small variation.

We argue that these extreme sulfate $\Delta^{17}O$ and $\delta^{18}O$ values reflect an extraordinary atmospheric and surface condition at a periglacial site during the Marinoan glaciation at ~ 635 Ma. Specifically, assuming fluxes (e.g., photosynthesis, respiration, and weathering) of atmospheric O_2 were in similar magnitudes as of today, the extremely negative sulfate $\Delta^{17}O$ values would indicate a high pCO_2 atmosphere, the highest ever in the last 750 million years. On the other hand, sulfate's negative $\Delta^{17}O$ signal disappeared as its $\delta^{18}O$ approaches ~+37‰, suggesting that microbial sulfur cycling in an evaporitic basin was so intense that the $\delta^{18}O_{sulfate}$ is approaching equilibrium with ambient water. This dataset present us two important challenges: 1) quantify atmospheric O_2 signal in initial sulfate derived from sulfide oxidation; and 2) understand processes preserving or erasing air O_2 signal in sulfate among diverse surface environments. The discovery and challenges presented here should become the focal point for the recently renewed interests in the oxygen side of the sulfate story.

Geochronology and geochemistry of the Fangcheng Neoproterozoic alkali-syenites in East Qinling orogen and its geodynamic implications

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The Fangcheng syenites, occurring in the northern Qinling tectonic domain of East Qinling orogen, consist mainly of nepheline syenite, aegirine syenite, and alkali-feldspar syenite. The syenites are of intermediate (SiO_2 = 54% ~ 62%), rich in alkali (K_2O+Na_2O = 12%~15%), aluminum (Al_2O_3 = 16.81% ~ 23.26%) and large ion lithophile elements (LILE), without any obvious Nb, Ta, Zr, and Hf anomalies. The Fangcheng syenites are geochemically characterized by relative enrichment of LREE, minor differentiation of HREE, significant negative Eu anomalies (Eu = 0.13 ~ 0.23), slightly high εNd(t) (-1.37 ~ -3.90), low T_{DM} (1364 ~ 1569 Ma), and high zircon saturation temperature (915~1044ºC). The syenite magmas probably originated from small proportion melting of upper mantle in an extensional regime of intraplate-anorogenic tectonic setting, and have been slightly contaminated by crustal materials during ascending and/or emplacement.

Our new LA-ICP-MS zircon U-Pb age data suggest that the Fangcheng alkaline syenites were generated in early Neoproterozoic (844.3± 1.6 Ma, MSWD = 0.86), implying that they are the oldest Neoproterozoic alkaline rocks ever recognized in the Qinling orogen as well as South China. It implied that the tectonic regime of Qinling region might have converted from post-collisional to intraplate-anorogenic at ~ 844 Ma. Therefore, it can also be inferred that the amalgamation of Rodina supercontinent along the Yangtze Craton margin terminated and the Qinling region transformed into an intraplate-anorogenic setting is no later than ~844 Ma.

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