Triple oxygen isotope composition of tropospheric O_2 during the Mesozoic from fossil vertebrate biominerals

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The ^{17}O anomaly of atmospheric O_2, $\Delta^{17}O[O_2]$ = –0.4 ± 0.1 ‰ [1, 2], reflects a balance between production of anomaly by photochemical reactions in the stratosphere and sequestration of anomaly to the hydrosphere driven by photosynthesis and respiration [2-4]. Thus $\Delta^{17}O[O_2]$ is a tracer of the global carbon cycle, and has been used as a basis for reconstructing atmospheric carbon dioxide levels in deep time [4, 5]. Here we further explore the use of vertebrate biominerals as recorders of $\Delta^{17}O[O_2]$, following the idea [5] that O in animal tissues in part derives from atmospheric O_2 consumed during respiration.

We present an extensive dataset of $\Delta^{17}O_{biomineral}$ from modern bird eggshells and mammal teeth that describes isotopic variability that is independent of the atmospheric $\Delta^{17}O[O_2]$ signal. Isotopic mass balance models of body water suggest that this variability is largely controlled by variable consumption of evaporated waters, including leaf waters, with relative humidity as the dominant control of their $\Delta^{17}O$ values. The mass balance model is a key aspect of a concordance approach for reconstructing atmospheric $\Delta^{17}O[O_2]$ from spectra of $\Delta^{17}O_{biomineral}$ values for contemporaneous assemblages of animals.

Fossil dinosaur eggshells indicate highly anomalous $\Delta^{17}O[O_2]$ values of ca. –2 ± 1 ‰ during the late Jurassic, and less extreme values during the mid- and late Cretaceous (-0.8 ± 0.5‰). The Jurassic values point to a unique mode of the carbon cycle unknown in more recent times. Assuming similar-to-present gross primary productivity and atmospheric O_2 levels, the late Jurassic $\Delta^{17}O[O_2]$ values indicate CO_2 levels in excess of ~1800 ppm. Alternatively, the late Jurassic $\Delta^{17}O[O_2]$ values are consistent with a lower CO_2 levels of ~1000 ppm if atmospheric O_2 was low (ca. 15%) or if primary productivity was low (ca. 50% present). Independent estimates of of primary productivity and pO_2 will help to refine $\Delta^{17}O[O_2]$-based estimates of pCO_2.

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