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Cenozoic and Mesozoic atmospheric carbon dioxide concentrations from triple oxygen isotope analyses of mammalian bioapatite

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Modern air O_2 has an oxygen triple isotope anomaly of $\Delta^{17}O$ = –0.4‰ (average of [1,2,3]) relative to a rocks and minerals defined terrestrial fractionation line (TFL). The anomaly is induced by respiration and by transfer of anomalous stratospheric O_2 to the troposphere. The production rate of stratospheric anomalous O_2 is proportional to the atmospheric CO_2 concentration[4,5]. Therefore, the magnitude of the anomaly of air O_2 is a measure for the atmospheric CO_2 level.

We demonstrate that the $\Delta^{17}O$ of air O_2 is transferred through inhaled air via body water to skeletal apatite of mammals. Laser fluorination analyses of recent mammals with body masses between ∼2 g and ∼5000 kg show that up to 50% of bioapatite oxygen sources from inhaled air O_2. The $\Delta^{17}O$ value decreases with decreasing body size. This is due to a higher proportion of oxygen derived from air O_2 in body water of small mammals. Large mammals obtain a proportionally higher amount of oxygen from drinking water and free H_2O in food, which have a $\Delta^{17}O$ value close to 0‰ . A detailed oxygen mass balance calculation agrees with the observed data.

Here we present oxygen triple isotope data from bioapatite of Oligocene and Eocene rodents as well as from Upper Jurassic (Kimmeridgian) Dryolestida. The Cenozoic samples originate from South German localities; the Jurassic samples are from the Guimarota coal mine in Portugal.

The results suggest atmospheric CO_2 concentrations of 500±190 ppmvfor the Upper Oligocene (25 Ma), 750±170 ppmv for the Middle Eocene (47 Ma) and 660±210 ppmv for the Kimmeridgian (153 Ma). The data agree within error with CO_2 data derived from $\delta^{13}C$ of marine phytoplankton, stomatal densities of leaves from land plants and $\delta^{11}B$ of marine biogenic calcium carbonate[6].

Our new proxy combines a high temporal resolution with small errors (±150-250 ppmv CO_2) and will permit the construction of an independent CO_2 profile for the Cenozoic and parts of the Mesozoic.

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