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# Reconstructing Antarctic Ice Sheet Oxygen Compositions Using Triple Oxygen Isotopes of Subglacial Opal: A Case Study from the Late Miocene Cooling Event

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Constraints on past sea level can provide key insights into the relationship between atmospheric $CO_2$ concentrations and ice sheet volume, thereby informing the vulnerability of modern ice sheets. Long-term, continuous records of global sea level have been derived using $\delta^{18}O$ values of benthic foraminifera ($\delta^{18}O_b$), which record the balance between water held in the ocean versus water trapped in continental ice sheets. However, these ice volume approximations are confounded by the fact that $\delta^{18}O_b$ values change as a function of ocean bottom water temperature and cannot account for spatiotemporal variation in the oxygen isotopic composition of ice sheets. Although efforts to refine $\delta^{18}O_b$ sea level estimates through bottom water temperature measurements and water partitioning models have provided more precise records, additional proxies for ice sheet oxygen compositions – especially those >600 ka – would be crucial to linking the benthic foraminifera $\delta^{18}O$ record to sea level estimates. Here, we present U-Pb dates and triple oxygen isotope analyses from opal that formed beneath the Antarctic Ice Sheet, showing that these samples represent a novel record of ice sheet $\delta^{18}O$ in the past.

We measured Antarctic subglacial opal that formed during the late Miocene cooling event (7 to 5 Ma), a climate interval characterized by global atmospheric and ocean cooling that was triggered by a ~100 ppm decline in atmospheric $CO_2$ concentration. Benthic $\delta^{18}O$ values increased sharply during this period, commonly interpreted as a rise in global ice volume. However, there is disagreement regarding whether the benthic signal resulted from Antarctic Ice Sheet expansion or deep ocean cooling. Triple oxygen isotope values from late Miocene opal regress to a meteoric water composition of approximately -50‰, suggesting that the $\delta^{18}O$ of ice in the East Antarctic interior regions during this period was between 1 and 9.5‰ higher than modern ice values. Using a simplified mass balance calculation, we explore the range of possible EAIS mass and sea level contribution given these new constraints on the $\delta^{18}O$ value of Miocene Antarctic ice.